General Works

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GAR-PIKES, OLD AND YOUNG.

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I.

SOME readers of The Popular Science Monthly may never have seen gar-pikes, or even heard of them. The word does not occur in some of the dictionaries, and the animals themselves are found alive only in certain parts of the world. So, before telling what gar-pikes do, it is necessary to explain what they are.

Fig. 1.—The Short-nosed Gar-Pike (*Lepidosteus platystomus*).
Nearly adult, one-fourth natural length. *O*, the gill cover, or operculum. *P*, the pectoral, and *Ve*, the ventral, fin of the left side. *D* and *A*, the dorsal and anal fins. *DF* and *VF*, the "fulcra" which cover the dorsal and ventral borders of the root of the tail. *X* indicates the point where the section shown in Fig. 3 was made. The scales are shown in the next figure.

In the first place, the gar-pike is not a weapon, but a *vertebrated animal*. The vertebrates include all animals having a spine or backbone made up of a series of segments or *vertebræ*. But this common definition is not wholly accurate. For the very young of man and monkeys, quadrupeds and birds, reptiles and fishes, have no skeleton at all; and some of the lowest fishes, the *Amphioxus* and the lamprey-eels, have no bones. So the vertebrates are now said to include all animals having a longitudinal axis or spine (whether membrane, cartilage, or bone) separating an upper or dorsal cavity, containing the spinal cord and brain, from a lower or ventral cavity, containing

the stomach, intestine, heart, and other organs of vegetative life. This is shown in Fig. 3.

Let us now go one step further and learn what kind of a vertebrate is the gar-pike. At present the most natural primary subdivision of the branch seems to be into three great groups. The highest

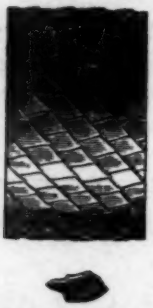


FIG. 2.—PART OF THE SIDE OF THE BODY OF *Lepidosteus platystomus*, Natural size, showing the arrangement of the enameled scales. Below is an outline of a single scale; the point is covered by the scale in front.

is the Mammalia, comprising our common quadrupeds, also bats, monkeys and men, seals and whales. The females of all these bring forth their young alive, and nourish them with milk.

Next come the Sauropsida, including birds, turtles, crocodiles, lizards, and snakes. Lastly, the Ichthyopsida, embracing the Batrachians (frogs, toads, and salamanders), and all other vertebrates.

Evidently, our gar-pike is neither a mammal nor a bird, a turtle, a snake, nor a lizard. It does look a little like an alligator, but it has not only fins and scales, but also *gills*, which are not known to exist in any reptile; while all the Ichthyopsida have gills during at least a part of their lives. The gar-pike is neither a frog nor a toad; it has scales and fin-rays unlike salamanders. Why, then, not call it a *fish?*

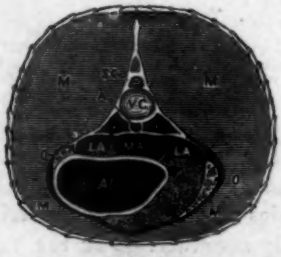


FIG. 3.—CROSS-SECTION (NATURAL SIZE) OF THE SHORT-NOSED GAR-PIKE (*Lepidosteus platystomus*),

Showing the general arrangement of the organs which is characteristic of vertebrates. The section is made in front of the ventral fins at the point indicated by *X* on Fig. 1. The cut surface is looked at from behind. Near the middle is the vertebral column or backbone (*VC*). Above it is the spinal cord (*SC*), surrounded by bony walls. Below are the abdominal viscera. *A* is the median aorta, *V V* the lateral veins. *MA* is the median channel of the air-bladder, and *LA*, *LA*, are its lateral chambers. The cavity of the stomach (*Al*) is on the left, and the liver (*L*), with two veins, on the right. *O*, *O* are the two ovaries, of which the left lies farther forward so that its section is smaller. The whole is surrounded by the muscular walls of the body (*M*, *M*, *M*, *M*), and this again is covered by the plates of the skin.

Because, unfortunately, we are not sure that there are any "fishes." The terms "beast, bird, and fish," notwithstanding common usage and the sanction of Scripture, are devoid of scientific accuracy. For "beast" includes turtles and alligators, and excludes the aquatic mammals, whales, porpoises, manatee, and dugong. "Bird" includes bats and pterodactyls, and excludes the ostriches and penguins, which cannot fly. So "fish" is not only held by some persons to embrace the aquatic mammals, but also, when employed in a stricter sense, it includes forms differing among themselves in many important points.

At any rate, the "fish-like vertebrates" present the following well-marked groups:

1. *Amphioxus lanceolatus;* the lancelet. A single genus with perhaps a single species, but so peculiar as to have received the following appellations: Branchiostoma, Cirrostomi, Pharyngobranchii, Leptocardia, Acrania, Entomocrania, Dermopteri.

2. Myzonts, or Marsipobranchii; the hag-fishes and lamprey-eels.

3. Plagiostomes, or Elasmobranchii; sharks and skates.

4. Holocephala; the *Chimæra* and *Callorhynchus.*

5. Ganoids; the sturgeons (*Acipenser* and *Scaphyrhynchus*); the spoonbill (*Polyodon*); the mud-fish (*Amia*); the gar-pike (*Lepidosteus*); and the *Polypterus* and *Calamoichthys* of Africa, with many fossil forms.

6. Dipnoans; the mud-fishes of Africa, South America, and Australia (*Protopterus*, *Lepidosiren*, and *Ceratodus*).

All of the above were formerly, and are now popularly, regarded as *fishes.*

But the fishes proper, or ordinary fishes, are now called:

7. Teleosts; the perch, salmon, cod, mackerel, and all others not included within the other six groups.

Some have included *Amphioxus* with the Myzonts; others the Plagiostomes with the Ganoids. The most natural combination seems to be that of the Ganoids with the Teleosts; and to this larger group the term Pisces has been applied. But for the present it is safer to recognize the distinctions, and to make our generalizations more exact.

What, then, is a gar-pike? Is it a Ganoid or a Teleost? Curiously enough, the prefix "gar" (signifying a dart or pointed weapon) is employed to designate two fishes, of which one (*Belone*) is a marine Teleost, and the other (*Lepidosteus*) is a fluviatile Ganoid. Both have long jaws with sharp teeth, but in other respects they are very unlike. It will be better to call *Belone* the "gar-*fish*" and *Lepidosteus* the gar-*pike.*[1]

The general appearance of the gar-pike is sufficiently indicated by

[1] These common names are very perplexing. Thus the true pike is *Esox.* The name dog-fish is popularly applied to *Menobranchus*, a batrachian; to *Amia*, a ganoid; and to *Acanthias*, a shark.

the figure. The body is an elongated cylinder covered with hard and shining scales closely joined, and leaving as vulnerable points only the throat and gills, the eyes, and the parts just under the pectoral fins. The tail is moderate in size and rounded, the longest rays a little above the middle, so that it is not quite symmetrical. Upon the hinder part of the back is the dorsal fin, and below the dorsal an anal fin, immediately in front of which is the vent or outlet of the alimentary canal. The paired fins, pectoral and ventral, occupy the places natural to them as representatives of the anterior and posterior limbs of salamanders and alligators.

The length of the head varies in the different species, but, whether longer or shorter, the jaws are furnished with rows of very sharp and closely-set teeth. The apparent form of these teeth is a simple elongated cone; but it has been shown by Prof. Jeffries Wyman that their surface is really deeply folded, so that a cross-section resembles that of the teeth of the curious fossil Batrachians, called, for that reason, Labyrinthodonts. The eyes are of moderate size. As with ordinary fishes, the ears do not appear externally. The nostrils are two pair of small holes at the tip of the snout, communicating with an olfactory sac on each side; the lining of this sac presents one median longitudinal and many transverse folds.

The genus *Lepidosteus*, according to Huxley, has not been found earlier than the Tertiary rocks; although the family *Lepidosteidæ* is represented by more or less numerous genera as far back as the Carboniferous and perhaps (by *Cheirolepis*) in the Devonian.

True gar-pikes are not found in Europe, Asia, Africa, or Australia, or in South America; while in North America they seem to be nearly confined to the Mississippi River and its tributaries, and the Great Lakes.[1]

Prof. Poey has also recorded the existence of a gar-pike in Cuba, a fact which is interesting, not as an indication of "manifest destiny," but as a memorial of the supposed ancient connection between the West India Islands and our continent. None have been found in salt-water, and the writer has no knowledge as to how far they enter the mixed water at the mouth of the Mississippi; but their tenacity of life encourages the belief that they might possibly adapt themselves to the ocean. Their introduction into New England waters would afford to Eastern zoölogists the much-desired opportunity of studying their development, of which nothing whatever is known.

We must now inquire whether there are more than one species of *Lepidosteus*.

Unfortunately, this question involves several others. For the genus *Lepidosteus*, established by Lacepede for the single species

[1] A few examples have been taken in Cayuga Lake, in Central New York, having probably entered by the canal at its northern end; it is said to occur in the Susquehanna River, Pennsylvania. It is lately reported that a species has been found in China.

osseus, has since been subdivided by some authors into *Lepidosteus*, *Cylindrosteus*, and *Litholepis*, or *Atractosteus*; and nearly forty specific names have been applied. One of these, *Sarchirus*, merely denotes the lobed state of the pectoral fin of the *young* gar (as will be shown further on), and most of the others seem to be based upon individual or geographical variations. Much more remains to be learned before the exact number of species can be ascertained; meantime, we may safely admit the three following:

L. osseus, the bony gar, having a long and narrow snout, and rarely attaining five feet in length; *L. platystomus*, the short-nosed gar, with a short and broad snout, as the name implies; and *L. adamantinus*, the alligator-gar or diamond-gar, with a short and wide snout, but attaining a greater size than the other two, and more common in the southern part of the Mississippi Valley. Probably the careful comparison of many individuals will oblige us to admit one or two additional species.

Notwithstanding, however, the peculiarities by which several of the species of *Lepidosteus* may be distinguished, so many and so obvious are the features which unite them together, and separate them from all other fishes, that they are recognized by all as belonging together, just as are the catfishes, the suckers, or the sturgeons.

Moreover, their internal structure, so far as it has been ascertained, presents a remarkable uniformity, whence we may infer that there is no important difference in their functions or habits, excepting in so far as may depend upon their circumstances, their food, etc. It is desirable to ascertain the extent of this variation, by accurate observation of carefully-determined examples, but on the present occasion we must be content, although unwillingly, with the assumption that what one gar has done another gar can do.[1]

Like most other New England zoölogists, the writer had been long obliged to content himself with dead gar-pikes, and with the somewhat unsatisfactory figures and descriptions which occur in a few zoölogical works. He had gained some more vivid impressions from the words and blackboard sketches of him who regarded "the establishment of the order of Ganoids as the most important advance which he had brought about in ichthyology."[2]

But even these privileges only increased the desire to behold the gar alive and active, and to realize the delight expressed by the great teacher when first enabled to observe them upon his journey to Lake Superior.

[1] Unwillingly, because all such assumptions are very undesirable. There have proved to be exceptions to nearly all general rules, whether of structure or of functions, as is shown in a paper by the writer, entitled "Is Nature inconsistent?"—(The *Galaxy*, April, 1876.)

[2] Although most other zoölogists have differed with Agassiz respecting the limits of the group, the name has been generally retained.

When, therefore, the writer found himself upon the Illinois River (at Peoria, Illinois), his steps almost instinctively sought the water, in the somewhat unreasonable expectation of being first greeted by a majestic "gar," rather than by some of the many kinds of ordinary fish so abundant in the Western rivers.

The first glance was disappointing. The river here widens into a basin known as Peoria Lake; and from the fishermen's pier, projecting some forty feet from the shore, could be seen no sign, near or remote, of the hoped-for mail-clad fish. The fishermen, who had not yet become acquainted with that unnatural perversity of naturalists which causes them to prize some things inversely as their beauty, their gentleness, and their commercial value, called attention to the "cats," "buffaloes," and other marketable fish swarming in the sunken pens, and promised to bring in some gars from their next haul; adding some emphatic statements as to the superabundance of these and of other such trash.

Just then, gliding slowly about very near the surface, and apparently undisturbed by the splashing of the bulky "cats" and "buffaloes," was seen a slender little fish less than three inches long. It was a young gar-pike. It might easily have escaped between the bars of the tanks, but instead remained within arm's-length of the edge of the open trap, moving gently to and fro as if courting observation.

A tin cup was anxiously brought: it was dipped into the water, slowly approached, and quickly lifted. The gar was there. But, floating as usual at the surface, a slight tilting of the cup spilt it back again into the water. To the astonishment of all, it soon reappeared in its former place, seeming actually to welcome death for the sake of (scientific) immortality.

By a second and more careful effort the young gar was secured, and soon transferred to the basin of water which was destined to be its home for three weeks.

During that time a part of each day was spent in observation of its form and its movements, and in comparing it with other gars, old and young.

Their Habits.—None of the young gars observed by the writer showed any disposition to attack each other or the small fishes placed with them; and the stomachs of the two adults examined with reference to this point contained only a few grasshoppers. But the many and sharp teeth are evidently well fitted for seizing living and active prey, and the fishermen accuse the gars of destroying large numbers of food-fishes. On this account, as also in revenge for the damage done by them when entangled in the nets, the fishermen are said to throw them out upon the bank to die, or to plunge them forcibly head first into the soft mud. More information is needed as to the food of the gar.

The following brief account of their manner of feeding is from a

report of some remarks of Prof. Agassiz on young, living gar-pikes from Lake Ontario, before the Boston Society of Natural History, in 1856:

"The manner of feeding also is unlike that of other fishes, and resembles that of reptiles. Other fishes take their food and swallow it at once, with open mouth. But this one (the young gar) approaches its prey (in this case small minnows) slyly, sidewise, and, suddenly seizing it, holds it in its jaws until, by a series of movements, it succeeds in getting it into a proper position for swallowing, as is the habit with lizards and alligators."

Before attaching much importance to the reptilian analogies here suggested, it should be ascertained whether the mode of swallowing above described is not followed by certain long-billed Teleosts (as *Belone*, etc.), and, on the other hand, discarded by the short-headed gar, whose jaws have nearly the form of the pickerel. Upon the whole, the gars and other typical Ganoids seem to have affinities with Batrachians rather than with scaly reptiles.

The flesh of the gar is soft, and speedily decays. In Wood's "Natural History," it is stated that "the flesh of the bony pike is said to be good;" and Prof. W. S. Barnard informs me that the gars, especially the young, are not infrequently used as food by whites in Wisconsin, and by both whites and negroes in Mississippi. Still, there is no reason for believing that the flesh is particularly desirable.

In this connection, it is worth noting that little use as food is made by man of the representatives of the Ganoids and the Plagiostomes, which, as shown by fossil remains, were created before the ordinary fishes. Some kinds of skates are eaten on the French coast, and sturgeons are known as "Albany beef," but no comparison can be made between them and the salmon, the cod, or the mackerel.

While watching the living gar, whether old or young, one of the first things noted is that it not only remains usually near the surface, but, at short intervals, actually protrudes the head from the water. In so doing, it turns partly over upon one side, emits a large bubble of air, executes a slight gulping movement of the jaws and throat, and sinks again below the surface; immediately afterward a few smaller bubbles escape from the gill-slit on each side of the neck. The foregoing is a very bald and inadequate description of a curious and, when first observed, astonishing operation. The movements are very rapid, and almost convulsive, as if the fish were suddenly oppressed by something, and hastened to remove it. The little gar first obtained almost invariably turned upon the left side, the air escaping from the right; this uniformity was not observed with the others. Occasionally they would open the jaws widely, as if gaping; and at other times the sides of the mouth were spread laterally.

With reference to the young gars from Lake Ontario already mentioned, Prof. Agassiz is reported as follows: "This fish is re-

markable for the large quantity of air which escapes from its mouth. The source of this air he has not been able to determine. At certain times it approaches the surface of the water, and seems to take in air, but he could not think that so large a quantity as is seen adhering in the form of bubbles to the sides of the gills could have been swallowed, nor could he suppose that it could be secreted by the gills themselves."

Since the exhalation of air from any source is evidently as easily performed below the surface, the periodical ascent of the gars goes far to show that there is likewise an inhalation. But as it was not easy to determine this, on account of the small size of the young gars and the difficulty of handling the older ones, the writer experimented upon another Western Ganoid, the *Amia*, or "mud-fish," or "dog-fish."

When placed in a tank the *Amia* kept near the bottom, and seemed to prefer the darker portions. But it came to the surface at pretty regular intervals, emitting one or two large bubbles from the mouth, and, on descending, several smaller ones from the opercular orifice.

The fish was gradually accustomed to having the body gently embraced by the hand about the middle.

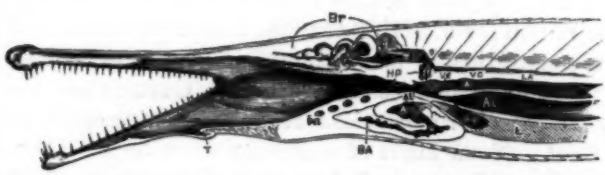


FIG. 4.—VERTICAL LONGITUDINAL SECTION OF THE HEAD OF *Lepidosteus platystomus*, ONE-HALF NATURAL DIAMETER.

Br, the brain cut on the median line so as to show the ventricles of the two hinder lobes, the cerebellum and optic lobes. *SC*, the spinal cord passing backward into the canal of the vertebral column (*VC*). *CT*, a mass of connective tissue filling the hinder part of the brain-cavity. *HP*, the right hypopharyngeal bone, just in front of the passage (*CH*) from the throat (*Al*) upward and backward into the air-bladder (*A*). *Ve* is a valve which seems to guard the opening from within; a corresponding valve is on the left side. *LA* is one of the openings from the median channel of the air-bladder into a lateral chamber. *L* is the liver, which terminates forward in a large blood-vessel, *HV*. *A* and *V* are the auricle and ventricle of the heart; *BA*, the branchial artery; and *ba*, the cut ends of the smaller arteries to the gills on the right side. *T* is the tongue.

Having been thus prepared, the fish was permitted to swim to and fro in the tank, but prevented from rising. It soon became uneasy, and, after a few not very violent efforts to disengage itself, emitted a large bubble of air.

Now, if this emission were all that was necessary we may suppose that it would have remained quiet for another period. On the contrary, after a second or two of repose (perhaps resulting from the habit of being satisfied after the respiratory act), the fish became more and more uneasy, moved rapidly to and fro, turned and twisted and lashed with its tail, and finally, by a violent effort, escaped from the hand. It rose to the surface, and, *without emitting any bubble, opened*

its jaws widely and apparently gulped in a large volume of air. It then descended and remained quiet for the usual interval.

FIG. 5.—VIEW FROM BELOW OF THE UPPER OR DORSAL WALL OF THE THROAT OF THE LONG-NOSED GAR (*Lepidosteus osseus*), ONE-HALF NATURAL DIAMETER.

The œsophagus is removed excepting that part of the dorsal wall (*Al*) which is closely attached to the air-bladder (*A*). Its cut edges are indicated by *x x*. *Ch* is the opening or "chink" leading into the air-bladder, and *C C* indicate projecting points at the sides of the chink. *HP*, hypopharyngeal bones armed with teeth.

The escaping air should be chemically examined. But, so far as the experiments go, it seems probable that, with both *Amia* and *Lepidosteus*, there occurs an inhalation as well as exhalation of air at pretty regular intervals, the whole process resembling that of the *Menobranchus* and other salamanders, and the tadpoles, which, as the gills shrink and the lungs increase, come more frequently to the surface for air.

But the reader may say: "These fishes have gills, of course; but have they also lungs?" To this the answer is both yes and no; for there are at least two different ways of interpreting certain facts; and some definitions are not as yet wholly agreed upon.

FIG. 6.—CROSS-SECTION OF THE AIR-BLADDER OF *L. osseus*, ONE-HALF NATURAL DIAMETER.

The central open space is the median channel; on each side is seen one of the numerous subdivisions of the lateral portions of the air-bladder. Above are the median aorta and the two lateral veins, as in Fig. 3.

The facts are as follows: the *Lepidosteus* and *Amia*, like many other fishes, have an *air-bladder*—a sac lying under the spine and above the alimentary canal, and communicating by a slit-like orifice with the upper side of the throat. With sturgeons and catfishes and most common fishes, the sac is nearly or quite simple, and the communication with the throat may be very narrow or even closed. Such fishes are not known to swallow air, and there is need of further information as to the composition and source of the contained gas. But the air-bladder of *Amia* and *Lepidosteus* is divided into many cells,

so as to resemble a frog's lungs; and the walls and partitions of these cells have many blood-vessels. These air-bladders are, in fact, more cellular and more vascular than the lungs of *Menobranchus*, or the hinder and larger portion of the lungs of serpents. And, in the light of the observations already recorded, there seems good reason for believing that pure air is inhaled and vitiated air exhaled whenever the fish rises to the surface.

It is worth noting, also, that both *Amia* and *Lepidosteus* are very tenacious of life, and endure removal from the water for a time much better than do the sturgeons, whose air-bladders are neither cellular nor vascular. The latter, also, are bottom-feeders, while the gars seem to keep near the surface of the water.

Why, then, are not these air-bladders lungs?

The most obvious objection is, that their openings are into the upper or dorsal side of the throat, while the glottis of batrachians, reptiles, birds, quadrupeds, and ourselves, communicates with the lower or ventral side.

This objection may be met in two ways. In the first place, if allowed, we should have to admit that all the so-called air-breathing vertebrates have organs (the lungs) which have no representative in the fishes, and that most of the latter have an organ (the air-bladder) which has no representative in the former.

It is true that some fishes have no air-bladder; but with some, as *Amphioxus*, the lamprey-eels, the sharks,[1] and the skates, we may infer that it has not yet become developed; while with others, as the flat fishes, the air-bladder may have been lost through what may be called a local retrograde metamorphosis.

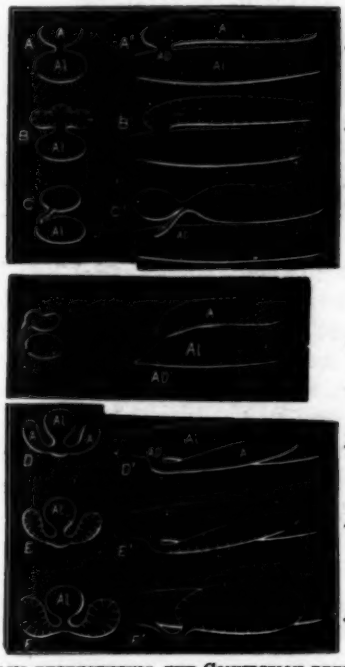
It is important to note, also, that an air-bladder and lungs have never been found in one and the same animal; and since arms, front-legs, flippers, and wings, are all regarded as modifications of the same organs, anterior limbs; and since, in many other cases, organs of very different size, form, complexity, and function, are considered as homologous, we shall be following precedent in admitting a willingness to regard air-bladders and lungs as modifications of the same organ.

But the true argument against the objection is derived from the existence of transition forms, or links, between air-bladders and lungs, as to the position of the organs themselves, and their communications with the alimentary canal.

With *Amia* and *Lepidosteus* the air-bladder and the opening of the duct are both dorsal. With the Brazilian fish called *Erythrinus* (as first stated by Johannes Müller, and lately verified by the writer), the duct opens upon one *side* of the throat. In the lately-discovered *Ceratodus* of Australia, as described by Günther, the sac and duct are single, but the former is vascular, and the latter enters at the left

[1] Maclay has figured a rudimentary air-bladder in certain shark-embryos.

of the ventral surface. With two African Ganoids, *Polypterus* and *Calamoichthys* (as also stated by Müller, and verified by the writer as to the latter genus) the sac is double, and communicates with the ventral side in the median line; but it is slightly cellular, as in *Menobranchus*.



A. Sturgeons and many Teleosts.

B. Amia and *Lepidosteus.*

C. Erythrinus.

G. Ceratodus.

D. Polypterus, Calamoichthys.

E. Lepidosiren, Protopterus.

F. Reptiles, birds, mammals.

FIG. 7.—DIAGRAMS REPRESENTING THE CONNECTION BETWEEN THE AIR-BLADDER OR LUNG AND THE ALIMENTARY CANAL IN CERTAIN VERTEBRATES.

Al, the alimentary canal. *A*, the air-bladder. *AD*, the air-duct.
The figures at the right show the alimentary canal and air-bladder from the left side; those at the left represent cross-sections more or less foreshortened in some cases.
A A' represent the simple condition-connections of the air-bladder in the sturgeons (*Acipenser*) and in most Teleosts where the air duct remains open. *B B'* represent the arrangement in *Amia* and *Lepidosteus*, where the duct opens upon the dorsal side of the throat, but the bladder is more or less cellular. The hinder end of the bladder is left open to indicate its great length in *Lepidosteus*. In *C C'* is shown the arrangement in *Erythrinus*. The bladder is still upon the dorsal side, but the front part is separated from the hinder two-thirds by a constriction, and the long duct passes forward from just behind the constriction to enter the left side of the throat. There are fibrous partitions in part of the bladder, but I do not know that they are vascular. The condition in *Ceratodus* is shown at *G*; the bladder is single but vascular, and the duct opens on the ventral side, but not in the middle line.
In the remaining figures the air-duct opens on the lower or ventral surface of the throat, and the air-bladder is in two parts, which unite at the duct, but separate backward and lie upon the sides of the stomach, or even to some extent upon its dorsal surface next the backbone. In the side-views only the left sac is seen; in the cross-sections the whole is foreshortened so as to bring it into one plane. In *Polypterus* and *Calamoichthys* the inner surface of the sacs is nearly smooth, but in *Lepidosiren*, as in the salamanders, it is more or less folded and vascular, and is also connected with the heart by special vessels. In the reptiles, birds, and mammals, the duct or trachea soon divides into the two bronchial tubes.

Finally, in the "mud-fishes" of Africa and South America (*Protopterus* and *Lepidosiren*) the duct is ventral, and the air-bladder is a double and lung-like sac with stiff walls.

This series seems to connect the air-bladder of the fishes with the lungs of the true aërial vertebrates, and to remove the objection

based upon the different position of the communication between them and the alimentary canal.[1]

But another and perhaps more weighty objection has been urged by Prof. Huxley. He says: "But such air-sacs are air-bladders and not lungs, because they receive their blood from the adjacent arteries of the body, and not direct from the heart, while their efferent vessels are connected only with the veins of the general circulation."

According to this view, therefore, the Dipnoans (*Protopterus* and *Lepidosiren*) have lungs, because the blood goes to the air-sacs by a pulmonary artery, and returns by a pulmonary vein into a left auricle; while the cellular and vascular air-bladders of *Amia* and *Lepidosteus* are not lungs, because such an arrangement does not exist.

Yet Prof. Huxley applies the name *placenta* to the vascular interdigitations by which the young of some sharks are connected with the mother, although they are developed from the yolk and not, as in mammals, from the chorion. It would be interesting to know whether the *nerves* of the air-bladder are the same as those of the lungs.

The best test of the naturalness of the definition would be furnished by the discovery of some form having the pulmonary vessels connected with an air-bladder lying upon the dorsal side of the alimentary canal. Meantime, since all are agreed upon the facts, the question concerns interpretations and definitions.

Whether or not the air-bladder of the gar-pike is entitled to the name of lung, we may admit that it corresponds with a lung in its essential connection with the alimentary canal, and apparently in its function as an organ for aiding the oxygenation of the blood.

MESMERISM, ODYLISM, TABLE-TURNING, AND SPIRITUALISM.[2]

By WILLIAM B. CARPENTER, C. B., M. D., LL. D., F. R. S.

I.

THE aphorism that "history repeats itself" is in no case more true than in regard to the subject on which I am now to address you. For there has been a continuity from the very earliest times of a belief, more or less general, in the existence of "occult" agencies, capable of manifesting themselves in the production of mysterious phenomena,

[1] In fact, considering the resemblance of the brains and enameled scales of *Lepidosteus* and *Polypterus*, and the differences of their air-bladders and ducts, one is inclined to regard the latter as of slight taxonomic importance.

[2] This discussion, in which the subjects are considered historically and scientifically, is an expansion of the lectures delivered at the London Institution.

of which ordinary experience does not furnish the *rationale*. And while this very continuity is maintained by some to be an evidence of the real existence of such agencies, it will be my purpose to show you that it proves nothing more than the wide-spread diffusion, alike among minds of the highest and of the lowest culture, of certain tendencies to thought, which have either created ideal marvels possessing no foundation whatever in fact, or have by exaggeration and distortion invested with a preternatural character occurrences which are perfectly capable of a natural explanation. Thus, to go no further back than the first century of the Christian era, we find the most wonderful narrations, alike in the writings of pagan and Christian historians, of the doings of the Eastern "sorcerers" and Jewish "exorcists" who had spread themselves over the Roman Empire. Among these the Simon Magus slightly mentioned in the book of Acts was one of the most conspicuous, being recorded to have gained so great a repute for his "magic arts" as to have been summoned to Rome by Nero to exhibit them before him; and a Christian father goes on to tell how, when Simon was borne aloft through the air in a winged chariot in the sight of the emperor, the united prayers of the apostles Peter and Paul, prevailing over the demoniacal agencies that sustained him, brought him precipitately to the ground. In our own day, not only are we seriously assured by a nobleman of high scientific attainments that he himself saw Mr. Home sailing in the air, by moonlight, out of one window and in at another, at a height of seventy feet from the ground; but eleven persons unite in declaring that Mrs. Guppy was not only conveyed through the air in a trance all the way from Highbury Park to Lamb's Conduit Street, but was brought by invisible agency into a room of which the doors and windows were closed and fastened, coming "plump down" in a state of complete unconsciousness and partial deshabille upon a table, round which they were sitting in the dark, shoulder to shoulder.

Of course, if you accept the testimony of these witnesses to the aërial flights of Mr. Home and Mrs. Guppy, you can have no reason whatever for refusing credit to the historic evidence of the demoniacal elevation of Simon Magus, and the victory obtained over his demons by the two apostles. And you are still more bound to accept the solemnly-attested proofs recorded in the proceedings of our law courts within the last two hundred years, of the aërial transport of witches to attend their demoniacal festivities; the belief in witchcraft being then accepted not only by the ignorant vulgar, but by some of the wisest men of the time, such as Lord Bacon and Sir Matthew Hale, Bishop Jewell, Richard Baxter, Sir Thomas Browne, and Addison, while the denial of it was considered as virtual atheism.

The general progress of rationalism, however, as Mr. Lecky has well shown, has changed all this; and to accept any of these marvels we must place ourselves in the mental attitude of the narrator of Mrs.

Guppy's flight, who glories in being so completely unfettered by scientific prejudices as to be free to swallow anything, however preposterous and impossible in the estimation of scientific men, that his belief in "spiritual" agencies may lead him to expect as probable.

If time permitted, it would be my endeavor to show you, by an historical examination of these marvels, that there has been a long succession of epidemic delusions, the form of which has changed from time to time, while their essential nature has remained the same throughout; and that the condition which underlies them all is *the subjection of the mind to a dominant idea.* There is a constitutional tendency in many minds to be seized by some strange notion which takes entire possession of them; so that all the actions of the individual thus "possessed" are results of its operation. This notion may be of a nature purely intellectual, or it may be one that strongly interests the feelings. It may be confined to a small group of individuals, or it may spread through vast multitudes. Such delusions are most tyrannous and most liable to spread when connected with religious enthusiasm: as we see in the dancing and flagellant manias of the middle ages; the supposed demoniacal possession that afterward became common in the nunneries of France and Germany; the ecstatic revelations of Catholic and Protestant visionaries; the strange performances of the Convulsionnaires of St.-Médard, which have been since almost paralleled at Methodist "revivals" and camp-meetings; the preaching epidemic of Lutheran Sweden, and many other outbreaks of a nature more or less similar. But it is characteristic of some of the later forms of these epidemic delusions that they have connected themselves rather with science than with religion. In fact, just as the performances of Eastern magi took the strongest hold of the Roman mind when its faith in its old religious beliefs was shaken to its foundations, so did the grandiose pretensions of Mesmer—who claimed the discovery of a new force in Nature, as universal as gravitation, and more mysterious in its effects than electricity and magnetism—find the most ready welcome among skeptical votaries of novelty who paved the way for the French Revolution; and this pseudo-scientific idea gave the general direction to the doctrines taught by Mesmer's successors, until, in the supposed "spiritualistic" manifestations, a recurrence to the religious form took place, which, I think, may be mainly traced to the emotional longing for some assurance of the continued existence of departed friends, and hence of our own future existence, which the intellectual loosening of time-honored beliefs as to the immortality of the soul has brought into doubt with many.

I must limit myself, however, to this later phase of the history, and shall endeavor to show you how completely the extravagant pretensions of mesmerism and odylism have been disproved by scientific investigation; all that is genuine in their phenomena having been accounted for by well-ascertained physiological principles; while the

evidence of their higher marvels has invariably broken down when submitted to the searching tests imposed by the trained experts whom I maintain to be alone qualified to pronounce judgment upon the matter.

Nothing is more common than to hear it asserted that these are subjects which any person of ordinary intelligence can investigate for himself. But the chemist and the physicist would most assuredly demur to any such assumption in regard to a chemical or physical inquiry; the physiologist and geologist would make the same protest against the judgment of unskilled persons in questions of physiology and geology; and a study of mesmerism, odylism, and spiritualism, extending over more than forty years, may be thought to justify me in contending that a knowledge of the physiology and pathology of the human mind, of its extraordinary tendency to self-deception in regard to matters in which its feelings are interested, of its liability to place undue confidence in persons having an interest in deceiving, and of the modes in which fallacies are best to be detected and frauds exposed, is an indispensable qualification both for the discrimination of the genuine from the false, and for the reduction of the genuine to its true shape and proportions.

And I further hold, not only that it is quite legitimate for the inquirer to enter upon this study with that "prepossession" in favor of the ascertained and universally admitted laws of Nature which believers in spiritualism make it a reproach against men of science that they entertain, but also that experience proves that a prepossession in favor of some "occult" agency is almost sure to lead the investigator to the too ready acceptance of evidence of its operation. I would be the last to affirm that there is not "much more in heaven and earth than is known to our philosophy;" and would be among the first to welcome any addition to our real knowledge of the great agencies of Nature. But my contention is, that no new principle of action has any claim to scientific acceptance, save upon evidence as complete and satisfactory as that which would be required in any other scientific investigation.

The recent history of Mr. Crookes's most admirable invention, the radiometer, is pregnant with lessons on this point. When this was first exhibited to the admiring gaze of the large body of scientific men assembled at the *soirée* of the Royal Society, there was probably no one who was not ready to believe with its inventor that the driving round of its vanes was effected by *light;* and the eminent physicists in whose judgment the greatest confidence was placed, seemed to have no doubt that this mechanical agency was something outside optics properly so called, and was, in fact, if not a new force in Nature, a new *modus operandi* of a force previously known under another form. There was here, then, a perfect readiness to admit a novelty which seemed so unmistakably demonstrated, though transcending all previ-

ous experience. But after some little time the question was raised whether the effect was not really due to action of *heat* upon the attenuated vapor of which it was impossible entirely to get rid; and the result of a most careful and elaborate experimental inquiry, in which Nature has been put to the question in every conceivable mode, has been to make it, I believe, almost if not quite certain that the first view was incorrect, and that heat is the real moving power, acting under peculiar conditions, but in no new mode.

No examination of the phenomena of spiritualism can give the least satisfaction to the mind trained in philosophical habits of thought, unless it shall have been, in its way, as searching and complete as this. And when scientific men are invited to dark *séances*, or admitted only under the condition that they shall merely look on and not inquire too closely, they feel that the matter is one with which they are entirely precluded from dealing. When, again, having seen what appears to them to present the character of a very transparent conjuring trick, they ask for a repetition of it under test-conditions admitted to be fair, their usual experience is that they wait in vain (for hours it may be) for such repetition, and are then told that they have brought an "atmosphere of incredulity" with them, which prevents the manifestation. Now, I by no means affirm that the claims of spiritualism are *dis*proved by these failures; but I do contend that, until the evidence advanced by believers in those claims has stood the test of the same sifting and cross-examination by skeptical experts that would be applied in the case of any other scientific inquiry, it has no claim upon general acceptance; and I shall now proceed to justify that contention by an appeal to the history of previous inquiries of the like kind.

It was about the year 1772 that Mesmer, who had previously published a dissertation "On the Influence of the Planets on the Human Body," announced his discovery of a universal fluid, "the immediate agent of all the phenomena of Nature, in which life originates, and by which it is preserved;" and asserted that he had further discovered the power of regulating the operations of this fluid, to guide its currents in healthy channels, and to obliterate by its means the tracks of disease. This power he in the first instance professed to guide by the use of magnets; but having quarreled with Father Hell, a Professor of Astronomy at Vienna, who had furnished him with the magnets with which he made his experiments, and who then claimed the discovery of their curative agency, Mesmer went on to assert that he could concentrate the power in and liberate it from any substance he pleased, could charge jars with it (as with electricity) and discharge them at his pleasure, and could cure by its means the most intractable diseases. Having created a great sensation in Bavaria and Switzerland by his mysterious manipulations, and by the novel effects which they often produced, Mesmer returned to Vienna, and undertook to cure

of complete blindness a celebrated singer, Mademoiselle Paradis, who had been for ten years unsuccessfully treated by the court physician. His claim to a partial success, however, which was in the first instance supported by his patient, seemed to have been afterward so completely disproved by careful trials of her visual powers, that he found himself obliged to quit Vienna abruptly, and thence proceeded to Paris, where he soon produced a great sensation. The state of French society at that time, as I have already remarked, was peculiarly favorable to his pretensions. A feverish excitability prevailed, which caused the public mind to be violently agitated by every question which it took up. And Mesmer soon found it advantageous to challenge the learned societies of the capital to enter the lists against him; the storm of opposition which he thus provoked having the effect of bringing over to his side a large number of devoted disciples and ardent partisans. He professed to distribute the magnetic fluid to his congregated patients from a *baquet* or magnetic tub which he had impregnated with it, each individual holding a rod which proceeded from the *baquet;* but when the case was particularly interesting, or likely to be particularly profitable, he took it in hand for personal magnetization. All the surroundings were such as to favor, in the hysterical subjects who constituted the great bulk of his patients, the nervous paroxysm termed the "crisis," which was at once recognized by medical men as only a modified form of what is commonly known as an "hysteric fit;" the influence of the imitative tendency being manifested as it is in cases where such fits run through a school, nunnery, factory, or revivalist-meeting, in which a number of suitable subjects are collected together. And it was chiefly on account of the moral disorders to which Mesmer's proceedings seemed likely to give rise that the French Government directed a scientific commission, including the most eminent *savants* of the time—such as Lavoisier, Bailly, and Benjamin Franklin—to inquire into them. After careful investigation they came to the conclusion that there was no evidence whatever of any special agency proceeding from the *baquet;* for not only were they unable to detect the passage of any influence from it that was appreciable, either by electric, magnetic, or chemical tests, or by the evidence of any of their senses; but, on blindfolding those who seemed to be most susceptible to its supposed influence, all its ordinary effects were produced when they were without any connection with it, *but believed that it existed.* And so, when in a garden of which certain trees had been magnetized, the patients, either when blindfolded, or when ignorant which trees had been magnetized, would be thrown into a convulsive fit if they believed themselves to be near a magnetized tree, but were really at a distance from it; while, conversely, no effect would follow their close proximity to one of these trees when they believed themselves to be at a distance from any of them. Further, the commissioners reported that, although some cures might be wrought by the mesmeric

treatment, it was not without danger, since the convulsions excited were often violent and exceedingly apt to spread, especially among men feeble in body and weak in mind, and almost universally among women; and they dwelt strongly also on the moral dangers which, as their inquiries showed, attended these practices.

Now, this report, although referring to a form of mesmeric procedure which has long since passed into disrepute, really deals with what I hold to be an important principle of action, which, long vaguely recognized under the term "imagination," now takes a definite rank in physiological science; namely, that in individuals of that excitable nervous temperament which is known as "hysterical" (a temperament by no means confined to women, but rare in healthy and vigorous men), the expectation of a certain result is often sufficient to evoke it. Of the influence of this "expectancy" in producing most remarkable changes in the bodily organism, either curative or morbid, the history of medicine affords abundant and varied illustrations; and I shall presently show you that it operates no less remarkably in calling forth movements which, not being consciously directed by the person who executes them, have been attributed to hypothetical occult agencies.

I shall not trace the further history of Mesmer, or of the system advocated by himself; contenting myself with one ludicrous example of the absurdity of his pretensions. When asked in his old age by one of his disciples why he ordered his patients to bathe in river-water in preference to well-water, he replied that it was because river-water is exposed to the sun's rays; and when further asked how these affected it in any other way than by the warmth they excited, he replied, "Dear doctor, the reason why all water exposed to the rays of the sun is superior to all other water is because it is magnetized—since twenty years ago *I magnetized the sun!*"

In the hands of some of his pupils, however, animal magnetism, or Mesmerism (as it gradually came to be generally called), assumed an entirely new development. It was discovered by the Marquis de Puysegur, a great landed proprietor, who appears to have practised the art most disinterestedly for the sole benefit of his tenantry and poor neighbors, that a state of profound insensibility might be induced by very simple methods in some individuals, and a state akin to somnambulism in others; and this discovery was taken up and brought into vogue by numerous mesmerizers in France and Germany, while, during the long Continental war, and for some time afterward, it remained almost unknown in England. Attention seems to have been first drawn to it in this country by the publication of the account of a severe operation performed in 1829, by M. Cloquet, one of the most eminent surgeons of Paris, on a female patient who had been thrown by mesmerism into the state of somnambulism; in which, though able to converse with those around her, she showed herself entirely insen-

sible to pain, while of all that took place in it she had subseqnently no recollection whatever. About twelve years afterward, two amputations were performed in our own country—one in Nottinghamshire, and the other in Leicestershire—upon mesmerized patients, who showed no other sign of consciousness than an almost inaudible moaning; both of them exhibiting an uninterrupted placidity of countenance, and declaring, when brought back to their ordinary state, that they were utterly unaware of what had been done to them during their sleep. And not long afterward Dr. Esdaile, a surgeon in Calcutta, gave details of numerous most severe and tedious operations performed by him, without the infliction of pain, upon natives in whom he had induced the mesmeric sleep—the rank of presidency surgeon being conferred upon him by Lord Dalhousie (then Governor-General of India), "in acknowledgment of the services he had rendered to humanity." The results of minor experiments performed by various persons, desirous of testing the reality of this state, were quite in harmony with these. Writing in 1845, Dr. Noble, of Manchester (with whom I was early brought into association by Sir John Forbes in the pursuit of this inquiry), said:

"We have seen a needle thrust deeply under the nail of a woman sleeping mesmerically, without its exciting a quiver; we have seen pungent snuff in large quantities passed up the nostrils under the same circumstances, without any sneezing being produced until the patient was roused, many minutes afterward; we have noticed an immunity from all shock when percussion-caps have been discharged suddenly and loudly close to the ear; and we have observed a patient's little-finger in the flame of a candle, and yet no indication of pain. In this latter case all idea of there having been courageous dissimulation was removed from our mind in seeing the same patient afterward evince both surprise and indignation at the treatment received; as, from particular circumstances, a substantial inconvenience was to result from the injury to the finger, which was by no means slight." [1]

This "mesmeric sleep" corresponds precisely in character with what is known in medicine as "hysteric coma;" the insensibility being as profound, while it lasts, as in the coma of narcotic poisoning or pressure on the brain; but coming on and passing off with such suddenness as to show that it is dependent upon some transient condition of the sensorium, which, with our present knowledge, we can pretty certainly assign to a reduction in the supply of blood caused by a sort of spasmodic contraction of the blood-vessels. That there is no adequate ground for regarding it as otherwise than *real*, appears further from the discovery made not long afterward by Mr. Braid, a surgeon practising at Manchester, that he could induce it by a very simple method, which is not only even more effective than the "passes" of the mesmerizer, but is, moreover, quite independent of any other will than that of the person who subjects himself to it. He found that

[1] *British and Foreign Medical Review*, April, 1845.

this state (which he designated as hypnotism) could be induced in a large proportion of individuals of either sex, and of all ranks, ages, and temperaments, who determinately fix their gaze for several minutes consecutively on an object brought so near to their eyes as to require a degree of convergence of their axes that is maintainable only by a strong effort.[1]

The first state thus induced is usually one of profound comatose sleep; the "subject" not being capable of being roused by sensory impressions of any ordinary kind, and bearing without the least indication of consciousness what would ordinarily produce intolerable uneasiness or even severe pain. But, after some little time, this state very commonly passes into one of somnambulism, which again corresponds closely on the one hand with *natural*, and on the other with *mesmeric*, somnambulism. In fact, it has been by the study of the somnambulism artificially induced by Mr. Braid's process that the essential nature of this condition has been elucidated, and that a scientific *rationale* can now be given of a large proportion of the phenomena reported by mesmerizers as having been presented by their somnambules.

It has been claimed for certain mesmeric somnambules, however, that they occasionally possess an intelligence altogether superhuman as to things present, past, and future, which has received the designation "lucidity;" and it is contended that the testimony on which we accept the reality of phenomena which are conformable to our scientific experience ought to satisfy us equally as to the genuineness of those designated as "the higher," which not only transcend but absolutely contradict what the mass of enlightened men would regard as universal experience. This contention, however, seems to me to rest upon an entirely incorrect appreciation of the probative force of evidence; for, as I shall endeavor to prove to you in my succeeding lecture, the only secure basis for our belief on *any* subject is the confirmation afforded to external testimony by our sense of the inherent probability of the fact testified to; so that, as has been well remarked, "evidence tendered in support of what is new must correspond in strength with the degree of its incompatibility with doctrines generally admitted as true; and, where statements obviously contravene all past experience

[1] Mr. Braid's peculiar success in inducing this state seemed to depend partly upon his mode of working his method, and partly upon the "expectancy" of his subjects. Finding a bright object preferable, he usually employed his silver lancet-case, which he held in the first place at ordinary reading-distance, rather above the plane of the eyes; he then slowly approximated it toward the middle point, a little above the bridge of the nose, keeping his own eyes steadily fixed upon those of his "subject," and watching carefully the direction of their axes. If he perceived their convergence to be at all relaxed, he withdrew the object until the axes were both again directed to it; and then again approximated it as closely as was compatible with their continued convergence. When this could be maintained for a sufficient length of time upon an object at no more than about three inches' distance, the comatose state generally supervened.

and the universal consent of mankind, any evidence is inadequate to the proof, which is not complete, beyond suspicion, and absolutely incapable of being explained away."

Putting aside for the present the discussion of these asserted marvels, I shall try to set before you briefly the essential characters which distinguish the state of somnambulism (whether natural or acquired) on the one hand from dreaming, and on the other from the ordinary waking condition. As in both these, the mind is in a state of activity; but, as in dreaming, its activity is free from that controlling power of the will by which it is directed in the waking state; and is also removed from this last by the complete ignorance of all that has passed in it, which is manifested by the "subject" when called back to his waking self, although the events of one access of this "second consciousness" may vividly present themselves in the next, as if they had happened only just before. Again, instead of all the senses being shut up, as in ordinary dreaming sleep, some of them are not only awake, but preternaturally impressible; so that the course of the somnambulist's thought may be completely directed by suggestions of any kind that can be conveyed from without through the sense-channels which still remain open. But, further, while the mind of the ordinary dreamer can no more produce movements in his body than his impressions on sense-organs can affect his mind, that of the somnambulist retains full direction of his body (in so far, at least, as his senses serve to guide its movements); so that he *acts* his dreams as if they were his waking thoughts. The mesmerized or hypnotized somnambule may, in fact, be characterized as a *conscious automaton*, which, by appropriate suggestions, may be made to think, feel, say, or do, almost anything that its director wills it to think, feel, say, or do; with this remarkable peculiarity, that its whole power seems concentrated upon the state of activity in which it is at each moment, so that every faculty it is capable of exerting may become extraordinarily intensified. Thus, while vision is usually suspended, the senses of hearing, smell, and touch, with the muscular sense, are often preternaturally acute, in consequence, it would seem, of the undistracted concentration of the attention on their indications. I could give you many curious instances of this, which I have myself witnessed, as also of the great exertion of muscular power by subjects of extremely feeble *physique;* but as they are all obviously referable to this one simple principle, I need not dwell on their details, preferring to narrate one which I did not myself witness, but which was reported to me on most trustworthy authority, of a remarkable manifestation of a power of imitative vocalization that is ordinarily attainable only after long practice. When Jenny Lind was singing at Manchester, she was invited by Mr. Braid to hear the performances of one of his hypnotized subjects, an illiterate factory-girl, who had an excellent voice and ear, but whose musical powers had received scarcely any cultivation. This girl, in the hyp-

notic state, followed the Swedish nightingale's songs in different languages both instantaneously and correctly; and when, in order to test her powers, Mademoiselle Lind extemporized a long and elaborate chromatic exercise, she imitated this with no less precision, though unable in her waking state even to attempt anything of the sort. Now, I wish you to compare this case with another, which was reported about the same time upon what seemed equally unexceptionable testimony. When Miss Martineau first avowed her conversion to mesmerism, the extraordinary performances of her servant J—— were much talked of; and, among other marvels, it was asserted that she could converse, when in her mesmeric state, in languages she had never learned, and of which she knew nothing when awake—the particular fact being explicitly stated that Lord Morpeth had tested this power and had found it real. Now, you will readily perceive that, supposing the testimony in these two cases to have been exactly the same, its probative force would have been very different. For the first of them, though unprecedented, presented no scientific improbability to those who were prepared, by their careful study of the phenomena of hypnotism, to believe that the power of imitative vocalization, like any other, might be intensified by the concentration of the "subject's" whole attention upon the performance. But it seemed inconceivable that an uneducated servant-girl could understand what was said to her in a language she had never learned; still more, that she should be able to reply in the same language. And the only possible explanation of the fact, *if fact it was*, short of a miracle, may have lain either in her having learned the language long before and subsequently forgotten it, or in her being able by "thought-reading" (which is maintained by some, even at the present time, to be one of the attributes of the mesmeric state) to divine and express the answer expected by Lord Morpeth. But the marvel was entirely dissipated by the inquiries of Dr. Noble, who, being very desirous of getting at the exact truth, first applied for information to a near relative of Miss Martineau, and was told by him that the report was not *quite* accurate; for, on Lord Morpeth putting a question to J—— in a foreign language, J—— had replied appropriately in her own vernacular. Her comprehension of Lord Morpeth's question, however, appeared in itself sufficiently strange to be suggestive of some fallacy; and having an opportunity not long afterward of asking Lord Morpeth himself what was the real state of the case, Dr. Noble learned from him that when he put a question to J—— in a foreign language she imitated his speech after a fashion by an unmeaning articulation of sound.

On the lesson which this case affords as to the credibility of testimony in regard to what are called the "higher phenomena" of mesmerism, I shall enlarge in my succeeding lecture, and at present I shall only remark that it was shown by careful comparison between the phenomena displayed by the same individuals, when "mesmerized"

in the ordinary way, and "hypnotized" by Mr. Braid's process, that there was no other difference between the two states than that arising from the special *rapport* between the mesmerizer and his subject; and that this was clearly explicable by the "expectancy" under which the "subject" passed into the state of second consciousness. For Mr. Braid found himself able, by assuring his "subjects" during the induction of the coma, that they would hear the voice of one particular person and no other, to establish this *rapport* with any person he might choose; the case being strictly analogous to the awaking of the telegraph-clerk by the clicking of his needles, of the doctor by his night-bell, or of the mother by her infant's cry, though all would sleep soundly through far louder noises to which they felt no call to attend. And thus, as was pointed out long since by Dr. Noble and myself, not only may the general reality of the mesmeric somnambulism be fully admitted, but a scientific *rationale* may be found for its supposed distinctive peculiarities, without the assumption of any special "magnetic" or "mesmeric" agency.

It is affirmed, however, that proof of this agency is furnished by the power of the "silent will" of the mesmerizer to induce the sleep in "subjects" who are not in the least aware that it is being exerted; and, further, to direct from a distance the actions of the somnambule. Doubtless, if satisfactory proof of this assertion could be furnished, it would go far to establish the claim. But nothing is more difficult than to eliminate all sources of fallacy in this matter. For while it is admitted by mesmerizers that the belief that the influence is being exerted is quite sufficient in habitual somnambules to induce the result, it is equally certain that such "sensitives" are marvelously quick at guessing from slight intimations what is expected to happen. And it has been repeatedly found that mesmerizers who had no hesitation in asserting that they could send particular "subjects" to sleep, or could affect them in other ways, by an effort of silent will, have utterly failed to do so when these subjects were carefully kept from any suspicion that such will was being exerted. Thus, Dr. Noble has recorded the case of a friend of his own, who, believing himself able thus to influence a female servant whom he had repeatedly mesmerized, accepted with the full assurance of confident faith a proposal to make this experiment in Dr. Noble's house instead of his own. The girl, having been sent thither with a note, was told to sit down in Dr. Noble's consulting-room while the answer was being written; her chair being close to a partially-open door, on the other side of which her master, whom she supposed to be elsewhere, had previously taken up his position. Although this gentleman had usually found two or three minutes sufficient to send the girl to sleep when he was in his own drawing-room and she was in the kitchen, the two being separated by intervening walls and flooring, yet when he put forth his whole force for a quarter of an hour within two feet of her, with only a partially-closed door

between them, it was entirely without result; and no other reason for the failure could be assigned than her entire freedom from expectancy. So, in another case, in which Mr. Lewis (accounted one of the most powerful mesmerists of his time) undertook to direct the actions of his somnambule in the next room, according to a programme agreed on between himself and one set of witnesses, while the actions actually performed were recorded and timed by another set, there was found to be so complete a discordance between the programme "willed" and the actions really executed as entirely to negative the idea of any dependence of the latter upon the directing power of the mesmerizer—the supposed relation having obviously grown up under the habitual repetition of a certain succession of performances (such as I had myself frequently witnessed), which the somnambule supposed himself expected to go through in the same order.[1] A converse experiment, performed by Dr. Elliotson himself, satisfied him that expectancy would take the place of what he maintained to be the real mesmeric influence. Having told one of his *habituées* that he would go into the next room and mesmerize her through the door, he retired, shut the door, performed no mesmeric passes, but tried to forget her, walked away from the door, busied himself with something else, and even walked into a third room; and, on returning in less than ten minutes, found the girl in her usual sleep-waking condition. The extreme susceptibility of many of these "sensitive" subjects further accounts for their being affected (without any intentional deceit) by physical impressions which are quite imperceptible to others: such as slight differences in temperature, when two coins are presented to them, of which one has been held in the hand of the mesmerizer; or two wineglasses of water, into one of which he has dipped his finger for a short time. But the *belief* that he has transmitted his influence in any mode is quite sufficient to produce the result, as was shown in an amusing case recorded by M. Bertrand, whose treatise on "Animal Magnetism" (Paris, 1826) is by far the most philosophical work extant on the subject. Having occasion to go a journey of a hundred leagues, leaving a female somnambule under the treatment of one of his friends, M. Bertrand sent him a magnetized letter, which he requested him to place on the stomach of the patient, who had been led to anticipate the expected results—mesmeric sleep, with the customary phenomena, supervened. He then wrote another letter which he did *not* magnetize, and sent it to her in the same manner, and with the same intimation. She again fell into the mesmeric sleep, which was attributed to the letter having been unintentionally impregnated by

[1] Mr. Lewis was challenged to this test-experiment, in consequence of his assertion that he had repeatedly induced the mesmeric sleep, and had directed the operations of his somnambules, by the exertion of his "silent will," from a distance. His utter failure to produce either result, however, under the scrutiny of skeptical inquirers, obviously discredits all his previous statements, except to such as are ready to accept without question the slenderest evidence of the greatest marvels.

M. Bertrand with the mesmeric fluid while he was writing it. Desiring to test the matter still further, he caused one of his friends to write a similar letter, imitating his handwriting so closely that those who received it should believe it to be his—the same effect was once more produced.

And so it was with the large number of experiments that were made within my own knowledge during the twenty years' attention that I gave to this subject, with a view to test the mesmerizer's power of inducing any of the phenomena of this state without the patient's consciousness. Successes, it is true, were not unfrequent; but these almost invariably occurred when the experiments were made under conditions to which the parties had become habituated, as in the case of Dr. Noble's friend. For his performances were so continually being repeated to satisfy the curiosity of visitors, that Dr. Noble's call at his house would have been sufficient to excite, on the part of the "subject," the expectancy that would have thrown her into the sleep. But when such expectancy was carefully guarded against, the result was so constantly negative as—I will not say to *disprove* the existence of any special mesmeric force, but to neutralize completely the affirmative value of the evidence adduced to *prove* it. For I think you must now agree with me that, if "expectancy" alone is competent to produce the results, as admitted by the most intelligent mesmerizers, nothing but the most rigid exclusion of such expectancy can afford the least ground for the assumption of any other agency. And my own prolonged study of the subject further justifies me in taking the position that it is only when the inquiry is directed, and its results recorded, by *skeptical experts*, that such results have the least claim to scientific value. The disposition to overlook sources of fallacy, to magnify trivialities into marvels, to construct circumstantial myths (as in the case of Miss Martineau's J—— and Lord Morpeth) on the slightest foundation of fact, and to allow themselves to be imposed upon by cunning cheats, has been so constantly exhibited by even the most honest believers in the "occult" power of mesmerism, as, not only in my own opinion, but in that of my very able allies in this inquiry, to deprive the unconfirmed testimony of any number of such believers, in regard to matters lying beyond scientific experience, of all claim to acceptance. In fact, the positions taken in regard to mesmerism by my friend Dr. Noble, as far back as 1845,[1] and more fully developed by myself a few years later on the basis of Mr. Braid's experiments, and of my own physiological and psychological studies,[2] have not only in our own judgment, but by the general verdict of the medical and scientific world, been fully confirmed by the subsequent course of events, the history of which I shall next proceed to sketch. —*Fraser's Magazine.*

[1] *British and Foreign Medical Review*, vol. xix.

[2] "Principles of Human Physiology," fourth edition, 1853; and *Quarterly Review*, October, 1853.

AQUEDUCTS.

THE remains of the lofty arcades upon which the aqueducts of ancient Rome were carried to the city have been justly classed among the finest and most picturesque ruins of the Roman Empire. Stretching across the plain eastward of the city, and towering high above the landscape, they are the first objects to fix the gaze and command the admiration of the stranger approaching the home of the Cæsars, and to fill his mind with visions of the strength and grandeur of the nation which mastered the world two thousand years ago. But these ruins speak not only of the mechanical skill and physical greatness of that vanished people, but also of their refinement and their acquaintance with the deeply-hidden laws of hygiene; for they well knew what has become known to us only after a lapse of twenty centuries, after the measurement of the heavens, and the discovery of the steam-engine, that for every large city an abundant supply of pure, fresh water is indispensable to the preservation of health. At the zenith of her grandeur, Rome had eleven distinct aqueducts, whose aggregate discharge was equivalent to a stream twenty feet wide by six deep, with a fall six times as rapid as that of the river Thames. The daily supply was in the proportion of 332 gallons to each inhabitant, and it was distributed to the palaces and humbler dwellings in every part of the city, as well as to innumerable fountains, many public wells and large reservoirs, to the numerous baths, and to several artificial lakes, where the emperors held their *naumachiæ*, or sham naval battles. These eleven constituted the most extensive and perfect system of aqueducts that has been possessed by any city even up to the present time. Their combined length was over 300 miles, 50 of which were above-ground either upon low substructures or more imposing arcades. The loftiest arcade was that belonging to the *Aqua Claudia* and the *Anio Novus;* it was in one place 109 feet high.[1] In respect to height of arcades, however, the aqueducts of Rome were less remarkable than several built by the emperors, about the same time, for certain provincial cities of the empire, and others of more recent times. Thus the Emperor Agrippa built an aqueduct for the city of Nemausus (Nîmes) in France, and carried it across the river Gard upon an arcade 180 feet high, and about 900 feet long. This splendid structure, still perfect, is now called the *Pont du Gard*, and is an object of attraction and astonishment to modern travelers. It consists of a triple row of arches, which in the two lower tiers are of wide span, and in the upper one narrow. This arcade "has no rival for lightness and boldness of

[1] The Roman foot was 11.6496 English inches; 5 feet made one passus; 1,000 passus one mile, or 1,618 English yards.

design among the existing remains of works of this class carried out by the ancient Romans." It is constructed entirely of freestone, to the covering of the upper row of arches. The stones were laid without cement, and each was raised by the lewis, the holes in which it was inserted being still visible exactly over the centre of gravity in every stone. Still more remarkable for height is one of the bridges of the aqueduct of Antioch, also built by the Romans. It is 700 feet long and 200 feet high. The lower part consists of a solid wall pierced by two arches, in the centre—one upon the ground, the other directly above. Along the top is a row of narrow arches. The design and workmanship of this structure are very rude. But in later times arcades of even greater height have been built. The arcade Delle Torri, near Spoleto, built in the seventh or eighth century A. D., is about 300 feet high and over 700 long. It consists of ten arches between lofty columns, and is remarkable as an early example of the pointed arch, as well as for lightness of design. The arcade of the Roquefavour Aqueduct across the river Arc is 262 feet high, and 1,287 feet long. This aqueduct supplies the city of Marseilles with water from the river Durance, 51 miles distant. It was constructed between 1839 and 1847, and has eight and a half miles of tunnels passing through three chains of limestone mountains. But the most imposing arcade in the world, as regards the combined effect of height and length, is that of Maintenon. It is about five-sixths of a mile long, and over 200 feet high. Louis XIV. built it for an aqueduct he projected to convey the water of the Eure from Pont Gouin to Versailles, a distance of about 33 miles. This great enterprise was abandoned in 1688, after an expenditure of four years and 22,000,000 francs. The design contemplated one arcade over three miles long, which in its highest part was to have been formed of three tiers of arches.

At the time that it was built, the Anio Novus, probably of all aqueducts in the world, drew its water from the most distant source. True, the conduit of the Aqua Marcia, one of the most important of the aqueducts of Rome, was longer, but its source was only 39 miles from the city, while that of the Anio was 42; the conduit of the one was 61 miles and 710 paces long, of the other 58 miles and 700 paces. There are at Carthage the remains of an aqueduct which is said to have been over 50 miles long, but it is impossible to tell whether it was built by the Carthaginians proper, or by the Romans who, long after the destruction of the old city, founded a new one on its ruins. The accompanying cut represents the remains, near Undena, of one of the arcades of this aqueduct. It comprised 1,000 arches, many of which were over 100 feet high. The ancient Peruvians are said to have built the most remarkable aqueducts in the world for length. Garcilasso speaks of one that was 360 miles long, and another 450, but these were for irrigating purposes, and they wound around the mountains and followed the surface of the valleys instead of crossing

them on arcades, and therefore differed essentially from the aqueducts that we have been considering. And, besides, the statements as to their length should not be received without caution, for, at the time that the Spaniards first visited the country, their belief in the marvelous had been very greatly enlarged by the discovery of a new world.

FIG. 1.—THE AQUEDUCTS. The Crossing in the Campagna near the Piscinæ and Roma Vecchia.

The longest aqueduct proper is that now building to convey the waters of the Somme-Soude, Soudon, and Dhuis, to Paris. It will be about 110 English miles long. The aqueduct of Roquefavour, already referred to, is 60 miles long, the longest in actual use.

The Romans appear to have got their knowledge of aqueduct-building, like most of their other knowledge, from the Greeks; for, while their first aqueduct, the *Aqua Appia*, was not constructed until 441 years after the building of the city, or 312 B. C., the Greeks had built aqueducts at Megara and Samos as early as 625 B. C., and at Athens in 560 B. C. But there is this difference, that the Greeks did not use arcades, which, however, were not rendered necessary by the topography of the country. At Samos, a tunnel four-fifths of a mile long, eight feet high and eight wide, was cut through a hill between the city and the water-source. A channel three feet wide was built within the tunnel, and an opening of the same width made to the surface from end to end, so that the fresh air came in contact with the water, which flowed into a conduit of masonry at the lower end, and thence directly to the baths, fountains, etc., of the city. This work

was constructed by Eupalinus, who had previously gained celebrity by building the aqueduct at Megara. At Athens the water-supply was drawn by subterranean conduits from Mounts Hymettus, Pentelicus, and Parnes, and received into reservoirs outside the city. Two conduits came from Mount Hymettus, and passed under the bed of the river Ilissus. Of course, it was necessary to supply fresh air to the water flowing through these subterranean channels, and that was done by piercing them with shafts at intervals of about fifty yards. Subterranean channels were also used to distribute the water through the city; they were of different forms, being round or square, and in some of them pipes of baked clay were laid. It is somewhat remarkable that these beneficent works were constructed by the wisdom of rulers who have come down to us branded as tyrants. The tyrants Theagenes of Megara, Polycrates of Samos, and Pisistratus of Athens, were the men who caused them to be built. Some of those old aqueducts still continue to supply Athens with water. The aqueduct of Syracuse which still supplies the city with an abundance of water, and which is remarkable for having a tunnel under the sea, between the city and the mainland, was built some time prior to the Athenian invasion, 412 B. C., for Thucydides mentions that it was partially destroyed by the invaders. But far more ancient than any yet referred to is the one at Jerusalem, built by Solomon, to conduct the water from the reservoirs, or "pools," that bear his name, to the city, a distance of six miles. It was formed by an earthen pipe ten inches in diameter, incased in stone and laid underground. It is still in use.

The periodical overflow of the Nile, the Tigris, and Euphrates, enabled the peoples of Egypt and Babylonia to store up vast quantities of water in artificial lakes, of which the Mœris in Egypt is a celebrated example, and the water was utilized as required, by surface-conduits or canals.

Let us now turn back to the aqueducts of Rome, and examine somewhat the details of construction. A recently-published work on the aqueducts comprehended in the archæology of Rome, by John Henry Parker, C. B., affords much interesting information in this connection. The facts are ascertained partly from the work of Sextus Julius Frontinus, who was superintendent of the aqueducts (*curator aquarum*) under the Emperors Nerva and Trajan (A. D. 94–107), and partly from explorations of the courses and remains of the aqueducts made by Mr. Parker himself. Of the eleven aqueducts already referred to, ten approached the city from the east and one from the west. Of the ten on the east, four had their sources near Subiaco, in a spur of the Apennines beyond Tivoli; the others took their rise in the lower lands nearer Rome. Two of these, the *Anio Vetus* and the *Anio Novus*, were fed by the river Anio, as is indicated by their names; the others received their waters from springs or small lakes,

and were called after their builders or projectors. The waters of the Marcian, the most prized for their purity and coldness, were collected from several springs. For the Anio Novus, which was unfailing as well as the most abundant of the aqueducts, the river Anio was arrested near its source by three gigantic walls at different levels, and formed into as many lakes, one below the other. Over these walls the waste-water fell in magnificent cascades, one of them over 150 feet high. The object of the lakes was to clarify the water; for the Anio, though usually a limpid stream, is liable to become muddy after a heavy rain. The sources of the Anio Novus and the Aqua Claudia are over 2,000 feet above the level of the city, and those of the Marcia and Anio Vetus are not very much lower. Descending from such a height and for distances varying in direct lines from 30 to 43 miles, the water would naturally acquire great velocity and tremendous force, which it was necessary to diminish, and that was done by making numerous angles in the conduits. The angles were made generally at every half-mile, and were points at which reservoirs (*castella*), or filtering-places (*piscinæ*), or both, with accompanying air-shafts, were built. These were surmounted by small towers. As an additional means of breaking the force of the water, the bottoms of the conduits were given a succession of short undulations. The conduits, reservoirs, and filtering-places, were lined with a cement called *opus signinum*, which is so compact that it will resist a hard tool. The art of making it has been lost. The conduits, always covered, were carried on arcades only where it was necessary to cross a valley or a plain above its level; for the rest of their way they ran in places upon the surface of the ground, but mostly below it. Thus of the 58 miles of the Anio Novus, 49 were underground. No two aqueducts were on the same level, and so, where their courses converged, it was both possible and convenient to carry one conduit upon another, because it was forbidden by law to erect a building within a certain number of feet on either side of an aqueduct; hence we find the Aquæ Marcia, Tepula, and Julia, carried from their point of convergence one above the other on one arcade, and the Aqua Claudia and Anio Novus on another. Each of the conduits was differently shaped, some having arched, others angular roofs. Besides the small reservoirs referred to as occurring at the angles of the conduits, there were larger ones at longer intervals. The ruins of one of these, belonging to the Aqua Marcia, are still to be seen near Carciano. It is a huge subterranean chamber divided by an arcade in the middle. Between five and seven miles from Rome were the great filtering-places to which most of the aqueducts converged. The waters, however, were not mingled, for each aqueduct had its separate chambers, though it was always within the power of the attendants (*aquarii*) to turn the water from one aqueduct into another at will. Of these

filtering-places, those of the Claudia and Anio Novus were underground, and now appear simply as mounds. The others were above-ground, but covered over. From this point two magnificent arcades, the Marcian and the Claudian, extended to the city—the one carrying three aqueducts, the other two. They were not more than 100 yards apart, and the Marcian was 30 feet high, the Claudian 50. The filtering-places were of peculiar construction and admirable design. They consisted of four chambers, two on a level with the conduit, and two directly below (Fig. 2). The water flowing into the first descended

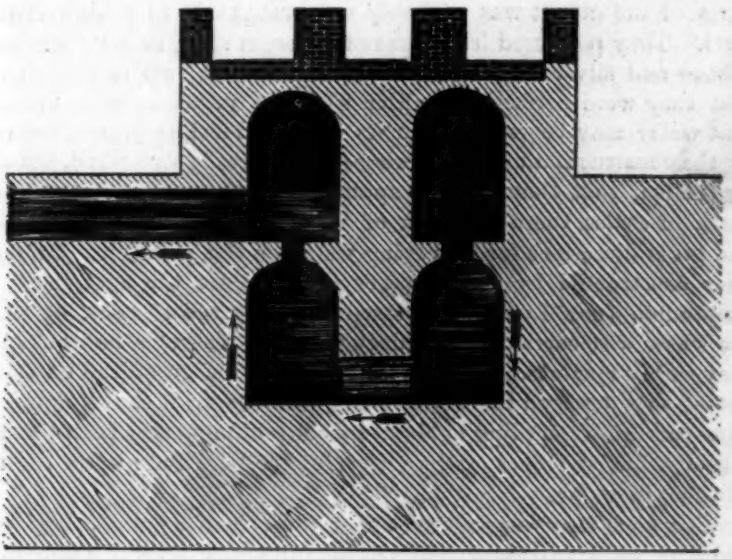


FIG. 2.—SECTION OF THE PISCINA OF THE ANIO NOVUS, at the Entrance into Rome in a Tower of the Wall of Aurelian and of the Gardens of the Sessorian Palace.

through an opening in the floor to the second, whence it flowed on through a perforated wall or grating to the third, ascending from that through an opening in the roof to the fourth, where it found its original level and reëntered the conduit. A stairway descending to an opening afforded access into the chambers beneath, and by the assistance of sluice-gates the water could be turned directly from the first chamber into the fourth, so that the mud could be cleaned out of the chambers below. It is remarkable that this ingenious device for filtering has not occurred to modern aqueduct-builders, for its simplicity and utility are conspicuous.

The details of distribution are interesting, but we have not space to go far into them. There were 247 main reservoirs in the city, from which the water was distributed to 19 barracks for the use of the army, 95 public establishments, 39 theatres and places of amusement, and 591 open reservoirs for the public. That was in the time of

Frontinus. The number of open reservoirs was afterward increased. Heavy penalties were inflicted for dipping a dirty vessel into one of these reservoirs. Of the total supply, a little over one-third was given to the public, and the remainder divided pretty evenly between private and imperial purposes. The wealthy had water brought into reservoirs within the courts of their residences, whence it was raised to the upper stories in buckets worked by windlasses. This method of supplying the upper stories is in use at the present time. The Romans had no pumps. Why the water was not conveyed upward in pipes does not appear, except that in regard to the more elevated parts of the city it was probably not brought in at a high enough level. They possessed lead pipes of different sizes, and stopcocks of bronze and silver, for these have been found in various places; and that they were perfectly familiar with the principle of hydraulics, that water may be returned to its original level, is proved not only by the construction of the filtering-places already described, but also by the fact that they actually applied the principle on a stupendous scale. Besides, there is a work of Vitruvius extant which recognizes and gives directions for conveying water on this principle. An aqueduct constructed by the Emperor Claudius, for the ancient city of Lugdunum (now Lyons), possessed two inverted siphons, by which the water was carried across deep valleys. There is no doubt that they were acquainted, too, with the poisonous action of lead on water; but, if that deterred them from raising the water, it shows they were more careful in guarding against unhealthful influences than we moderns are, for lead pipes are in general use to distribute water through our houses to-day.

The aqueducts were placed under the care of a *curator aquarum*, and afterward, in the time of Diocletian, under several magistrates, called *consulares aquarum*. The actual attendants numbered 700, and were divided into the *familia publica* and the *familia Cæsaris*. The former, 240 in number, were paid by the state; the latter, 460, by the emperor. With regard to the cost of building the aqueducts, it seems to have been defrayed, in the majority of cases, out of government funds; but it is recorded in an inscription on the Porta Maggiore, a gate of the city over which the conduits of the Claudia and Anio Novus were carried, that those two aqueducts were built by the Emperor Claudius at his own expense. This gate affords a clew to the reason why arcades instead of solid walls were used to carry the aqueducts across the plains: it was not solely for economy's sake, nor for beauty's; but while those considerations, no doubt, were entertained, the main object was, to avoid interference with the freedom of travel.

The aqueducts were all destroyed in the Gothic wars under Vitiges and Totila, but the most important of them were restored either by Belisarius or Narses. These, however, fell gradually into decay, and ultimately became useless. Pope Paul III. (1540) restored to use the

aqueduct on the west side of Rome; and Sixtus V. (1585) restored the aqueduct of Trajan by mistake for the Marcian. These two, the former called Paola, and the latter Felice, continued to be the only means of supply until 1870, when the real Marcian was restored by a company of Englishmen and Romans. The water is brought as far as Tivoli in a stone conduit, and the rest of the way in cast-iron pipes. It has sufficient pressure to supply the tops of all the houses.

FIG. 3.—RESERVOIR OF AQUA MARCIA. (Interior.)

Reference has been made to the aqueduct now building for Paris. The supply of water required is 22,000,000 gallons per day, and the aqueduct was designed to convey that quantity. It is intended for household use only, the existing supply, which is abundant for other purposes, having become somewhat polluted. It was calculated that the aggregate yield of the three rivers which are to be turned to account would be 28,000,000 gallons per day; but subsequent observation has shown that in very dry seasons it falls considerably below the quantity required. It was therefore found necessary to sink wells or shafts into the chalky formation in which the rivers have their rise, to artificially increase the supply. The plan comprises conduits for collecting the waters from the several sources called "conduits of derivation," and a main aqueduct to which these converge. The former are together about 50 English miles long, and the latter is 110. The main aqueduct has a fall of 73⅔ feet, and terminates in service-reservoirs at Belleville 83⅔ feet above the level of the city. Along

the course of the main and subsidiary conduits are 17 bridges, 3¾ miles of arcade, 4⅛ miles of siphon, and 17⅛ miles of tunnel. The work is done under the direction and supervision and in accordance with the designs of M. Belgrand. The total estimated cost, including $900,000 paid for injury to riparian rights, is $5,200,000.

The aqueduct which supplies the city of Manchester (England) with water is remarkable for its system of impounding reservoirs, comprising seven, with dams varying from 70 to 100 feet in height. The work was begun in 1848, and had not been completed in 1874, although it was far enough advanced to supply the city with water. The city of Glasgow is supplied by the Loch Katrine Aqueduct, 35 miles long, which conveys the water of the famous lake of that name. It consists of a conduit of masonry 8 feet deep, 8 wide, and 27 miles long, and two lines of cast-iron pipes, between the city and the service-reservoirs, 8 miles long. The conduit between Loch Katrine and the service-reservoirs is for the most part a tunnel through solid rock. It crosses some ravines on stone or iron arcades, and others by siphons. It is capable of discharging 50,000,000 gallons per day. It was opened by the queen with appropriate ceremonies in October, 1859. The work was begun in 1855, and finished in 1860. The cost, exclusive of facilities for distribution, was $3,340,000.

In the autumn of 1873 was finished the aqueduct designed by Herr Carl Junker, of Vienna, and constructed by Mr. Antonio Gabrielli, of London, to convey the water of two springs (the Kaiserbrunn and Stixenstein), situated at the foot of the Styrian Alps, to Vienna, a distance of 56½ miles. The conduit, which varies in size from 4½ × 2½ feet to 6½ × 4 feet, and is faced with polished cement, to facilitate the flow of the water, is always six feet below the surface of the earth or embankment through which it is carried. The object aimed at is to keep the water cold in summer and from freezing in winter. It has several splendid arcades, chief among which are one at Baden, another at Mödling, and a third at Liesing. The former is 96 feet high, about 2,000 feet long, and comprises 43 arches. The aqueduct delivers about 20,000,000 gallons a day. It was begun in 1869, and its cost was $10,000,000.

But, in regard to water-supply, the Roquefavour Aqueduct, referred to previously, is by long odds the most remarkable. The conduit is 7 feet deep, 30 wide at the top, and 10 at the bottom. It discharges 11 tons of water per second, or about 285,000,000 gallons per day. The water is used for the city of Marseilles, and to irrigate 25,000 acres around it.

In our own country there are several noted aqueducts—as the Cochituate at Boston, the Washington Aqueduct, and Croton at New York. The method employed by the cities of Chicago and Milwaukee to obtain their water-supply is unique. The water of Lake Michigan is brought into the city by a tunnel from a sufficient distance off

to insure its being pure, and is then pumped up into service-reservoirs, whence it is distributed in the usual manner. The Chicago tunnel is three miles long, that of Milwaukee is shorter.

The Washington Aqueduct leads from a reservoir which impounds the river-water at the Potomac Falls, is 16 miles long, and supplies the cities of Washington and Georgetown. Its capacity is 70,000,000 gallons per day. The water is conveyed in a brick-and-rubble masonry conduit, of circular form, to the service-reservoir five miles from the city, and the rest of the way in three large cast-iron pipes capable of delivering 30,000,000 gallons per day. This aqueduct was constructed at the expense of the United States Government, and cost $3,000,000. It has several fine bridges, of which the most notable is the one across Cabin John Creek. This is a single granite arch, 100 feet high and 220 long. Another remarkable example of the wide, single arch occurs on the Lisbon Aqueduct, finished in 1738. It is 115 feet wide and 250 high.

By far the finest aqueduct in America is the Croton. This was begun in 1837, and finished in 1842, at a cost of $8,575,000, without the means of distribution, which cost $1,800,000 more. The length of conduit from the impounding to the receiving-reservoirs in Central Park is 38½ miles, for 33 of which the conduit is built of stone, brick, and cement, arched above and below, 8 feet 5 inches high, 6½ feet wide at the bottom, and 7⅔ at the top. The water crosses Harlem River in two cast-iron pipes 3 feet in diameter, and one wrought-iron pipe 7 feet 6 inches in diameter, laid upon High Bridge, a magnificent granite arcade 1,460 feet long and 114 high. It comprises 15 arches, 7 of which have 50 feet span, and 8, those over the river, 80 feet. The fall is 1.10 foot per mile, the velocity of the water 1½ mile an hour, and the possible discharge 115,000,000 gallons per day.

For the first six years after the completion of the aqueduct, the quantity of water used was only 18,000,000 gallons per day, but it has now increased to over 88,000,000. The supply is drawn from Croton River, a small stream that flows into the Hudson, a short distance above Sing Sing. The river was arrested by a dam 40 feet high, and made to form what is now called Croton Lake. The mouth of the aqueduct is 12 feet below the surface of the lake, whereby it is protected from freezing up in winter, and the water is obtained pure and cool in summer. The lake has an area of 400 acres, and usually affords a daily supply of 50,000,000 gallons; but this fell off, during a severe drought seven or eight years ago, to only 27,000,000, and since then another source has been added by damming up the western branch of Croton River. The receiving-reservoirs, two in number, are located in Central Park: the "old" covers 35 acres, and holds 150,000,000 gallons; the "new" covers 100 acres, and holds 1,030,000,000. The distributing-reservoir is situated 2¼ miles farther down, between Fifth

and Sixth Avenues, Fortieth and Forty-second Streets. Its walls are 45 feet high, and they inclose a little more than 4 acres. The water is brought down in five lines of iron pipe, two of which are 30 inches in diameter, two three feet, and one four feet. The distributing-pipes, ramifying throughout the city, are about 340 miles long. The "mains" are laid near the sidewalks on either side of the streets, and at every crossing are provided with branches for supplying the adjacent buildings. These branches are provided with stopcocks for turning off the water when necessary. The higher parts of the city lying north of Manhattan Valley are supplied from a tower and reservoir recently built on high ground near One Hundred and Seventy-third Street and Tenth Avenue, to which the water is raised by powerful pumps. The reader will have been struck with the similarity between this aqueduct and those of ancient Rome; it remains to be shown that there is one other point of resemblance, in the air-shafts that are built at intervals of a mile. They rise 14 feet above the ground, and, like the old Roman ones, are in the form of towers. Every third one is provided with a door and way of access into the conduit. But the conduit is without the filtering-places and the angles. The conduit does, indeed, make several curves of 500 feet radius, but these are for changing the course of the aqueduct to avoid obstacles, instead of for breaking the force of the water, which in fact is unnecessary, the inclination being, as already shown, insignificant. The level of Croton Lake is about 115 feet above that of Manhattan Valley, and when the old reservoir in Central Park was yet building, the citizens of New York were afforded the magnificent spectacle of a vertical column of water shooting up over 100 feet from the bottom of the valley.

In connection with our subject, though not strictly belonging to it, may be mentioned the fact that canals are in many places carried across valleys and rivers upon bridges. Examples have long existed on the Languedoc Canal in France. The first in England was the Barton Bridge, which carries a canal across the river Irwell 39 feet above the surface. It was constructed by Brindley, for the Duke of Bridgewater. Says a contemporary English writer: "It was commenced in September, 1760; and in July of the following year the spectacle was first presented, in this country, of vessels floating and sailing across the course of the river, while others in the river itself were passing under them." The Lancaster Canal has one of five arches of 72 feet span each, and 65 feet high, across the river Lune. Later and more celebrated examples, though, are those of Pont-y-Cysylte and Chirk in Wales. The former, constructed by Mr. Telford, "is justly celebrated for its magnitude, simplicity of desgin, and skillful disposition of parts, combining lightness with strength in a degree seldom attempted. It consists of cast-iron arches resting on pillars of stone; the length is 1,000 feet, the number of arches 19, and the height 126 feet." In this country these bridges are numerous, there being

no less than 32 on the Erie Canal. The finest of them are two across the Mohawk River, a third at Richmond over the Seneca River, and a fourth across the Genesee at Rochester. The latter is a splendid stone arcade 920 feet long, having six cut-stone arches of 52 feet span. A wire suspension-bridge of seven spans, each 160 feet long, conveys the Pennsylvania Canal across the Alleghany River at Pittsburg.

GRAVITATION, AND HOW IT WORKS.

By GRANVILLE F. FOSTER.

"The force of gravity acts on bodies directly in proportion to the quantity of matter in each."

"The force of gravity decreases in the reciprocal proportion of the square of the distance."—(Orr's "Circle of the Sciences," vol. vi., p. 1.)

AMONG students of natural philosophy no facts are more frequently misunderstood than those pertaining to the laws of gravitation. It is readily admitted that if a body A exerts on B a certain force of attraction, if A's mass be doubled, then will A's attractive influence on B be doubled also, but the fact is not so apparent that any two bodies, whatever their disparity of mass, or however great their distance apart, will attract each other with *precisely* equal forces; and that if, for instance, the mass of A be doubled, not only will A's attraction for B be doubled, but at the same time B's attraction for A will be doubled also. The pen I hold in my hand attracts the sun with precisely the same amount of force that the sun attracts the pen, and, if either the mass of the pen or sun be doubled, the *mutual* attraction will be doubled also. The first law of gravitation most certainly teaches that the earth, so insignificantly small as compared with the sun, both in volume and mass, attracts the sun with a force exactly equal to that which, being by the sun exerted on itself, reduces it to obedience, and compels it to make its annual revolution. So, too, the moon and the earth mutually and equally attract each other.

The fact that the forces of attraction between two bodies are equal may be easily explained as follows: Let there be five bodies, A, B, C, D, E, and let A be so situated as to be at equal distances from the other four: then it is evident that the forces which measure the mutual attractions of (A and B), (A and C), (A and D), and (A and E), are equal. Calling the force which A exerts on B, or B exerts on A, *one*, then will the sum of the forces which B, C, D, and E exert on A be equal to *four*, but the sum of A's attractions for B, C, D, and E, will also be equal to *four*, since A's attraction for B is in no way

either increased or diminished by the fact that at the same time it also exerts an attraction on C, D, or E. Now, let B, C, D, and E, be united into one mass, F, and it will be readily perceived that the truth of the foregoing statements cannot thereby be affected.

As a general formula the law of gravitation may be enunciated as follows: "If one of the masses contain *m* units of mass, and the other *one* unit, the force will be *m* times as great as though they were both units of mass; but if the second body contain *n* units of mass, the attraction will be *n* times as great as before; that is, *m n* divided by the square of the distance between the bodies."

Now, suppose A and F free to move, then on meeting A will have moved over four-fifths of the distance between A and F, and F during the same time will have moved over one-fifth of the same distance; that is to say, the velocity of A has just been equal to four times that of F, and this is just what might have been expected from what is known of the laws of force. Suppose A and F to be placed where friction and other obstacles to motion do not exist, the velocities of the bodies will be indirectly as their masses, if the respective forces exerted on the bodies be equal; that is, a force which would propel a body with a certain velocity would propel another body one-quarter of the mass of the former with four times the velocity. In the case supposed, since A is one-quarter of the mass of F, a given force *must* necessarily move A over four times the space and with four times the velocity that it is able to move F, and when A and F meet the momenta of A and F will be respectively equal.

The truth that two bodies mutually and equally attract each other is also abundantly proved in astronomy. Take the case of the earth and moon. The earth by its attraction compels the moon to make around it as a centre her monthly revolution; but it is equally true that the moon compels the earth to move around the centre of gravity of the earth and moon, which centre, on account of the earth's mass being over eighty times that of the moon, is distant from the earth's centre a little over 2,000 miles, and this motion of the earth is performed in precisely the time of the lunar revolution, namely 27⅓ days. Now, it will require but little reflection to perceive that to move the earth in a circle with a radius of a little more than 2,000 miles, and the moon in a circle with a radius of nearly 240,000 miles, would require equal forces. The same thing is true of the sun, which is obliged by the combined forces of the planets to revolve around the centre of gravity of the solar system, and on making the necessary calculations we find that the force exerted on the planets by the sun just equals the force exerted by the planets on the sun.

Weight has been defined as the measure of the earth's attraction. A body weighing one pound attracts the earth and is attracted by it with a force of one pound, but the same body at the sun's surface would attract the mass of the sun with a force of twenty-seven pounds,

since its weight has been increased twenty-seven times by the sun's attraction.

We have hitherto considered the *mutual* attraction of *two* bodies, but now let a third be introduced, as, for instance, in the case of A and F, let G be placed at equal distances from A and F, and let the relative masses of A and F be as stated before in this paper: then will the force which measures the *mutual* attraction of F and G be equal to four times the force which measures the *mutual* attraction of G and A, or, in other words, F will attract G with four times the force that A will attract G. Lastly, let G's mass equal A's mass, and let G be placed at double the distance from F that A has been placed: then, according to the second law of gravitation, the units of force which measure the *mutual* attraction of A and F will be four times the force which measures the mutual attraction of G and F.

ON THE HABITS OF ANTS.

By SIR JOHN LUBBOCK, Bart.

THE anthropoid apes no doubt approach nearer to man in bodily structure than do any other animals; but when we consider the habits of ants, their social organization, their large communities, elaborate habitations, their roadways, their possession of domestic animals, and even in some cases of slaves, it must be admitted that they have a fair claim to rank next to man in the scale of intelligence. They present, moreover, not only a most interesting but also a very extensive field of study. In this country we have nearly thirty species; but ants become more numerous, in species as well as individuals, in warmer countries, and more than seven hundred kinds are known. Even this large number certainly is far short of those actually in existence.

I have kept in captivity nearly half of our British species of ants, and at the present moment have in my room more than thirty nests, belonging to about twenty species, some of which, however, are not English. No two species are identical in habits, and on various accounts their mode of life is far from easy to unravel. In the first place most of their time is passed underground; all the education of the young, for instance, is carried on in the dark. Again, ants are essentially gregarious; it is in some cases difficult to keep a few alive by themselves in captivity, and at any rate their habits under such circumstances are entirely altered. If, on the other hand, a whole community is kept, then the greater number introduces a fresh element of difficulty and complexity. Moreover, within the same species, the individuals seem to differ in character, and even the same individual

will behave very differently under different circumstances. Although, then, ants have attracted the attention of many naturalists—Gould, De Geer, Swammerdam, Latreille, Leeuwenhoeck, Huber—and have recently been the object of interesting observations by Frederick Smith, Belt, Moggridge, Bates, Mayr, Emery, Forel, and others, they still present one of the most promising fields for observation and experiment.

The larvæ of ants, like those of bees and wasps, are small, white, legless grubs, somewhat conical in form, being narrower toward the head. They are carefully tended and fed, being carried about from chamber to chamber by the workers, probably in order to secure the most suitable amount of warmth and moisture. I have observed also that they are very often sorted according to age. It is sometimes very curious in my nests to see them divided into groups according to size, so that they remind one of a school divided into five or six classes. When full grown they turn into pupæ, sometimes naked, sometimes covered with a silken cocoon, constituting the so-called "ant-eggs." After remaining some days in this state, they emerge as perfect insects. In many cases, however, they would perish in the attempt, if they were not assisted, and it is very pretty to see the older ants helping them to extricate themselves, carefully unfolding their legs and smoothing out the wings, with truly feminine tenderness and delicacy.

Under ordinary circumstances an ants' nest, like a beehive, consists of three kinds of individuals: workers, or imperfect females (which constitute the great majority), males, and perfect females. There are, however, often several females in an ants' nest; while, as we all know, there is never more than one queen in a hive. The queens have wings, but after a single flight they tear off their own wings, and do not again quit the nest. In addition to the ordinary workers there is in some species a second, or rather a third, form of female. In almost any ants' nest we may see that the workers differ more or less in size. The amount of difference, however, depends upon the species. In *Lasius niger*, the small brown garden ant, the workers are, for instance, much more uniform than in the little yellow meadow ant, or in *Atta barbara*, where some of them are more than twice as large as others. But in certain ants there are differences still more remarkable. Thus, in a Mexican species, besides the common workers, which have the form of ordinary neuter ants, there are certain others in which the abdomen is swollen into an immense subdiaphanous sphere. These individuals are very inactive, and principally occupied in elaborating a kind of honey.[1] In the genus *Pheidole*—very common in Southern Europe—there are also two distinct forms without any intermediate gradations: one with heads of the usual proportion, and a second with immense heads provided

[1] Westwood, "Modern Classification of Insects," vol. ii., p. 225.

with very large jaws. These latter are generally supposed to act as soldiers, and the size of the head enables the muscles which move the jaws to be of unusual dimensions, though the little ones are also very pugnacious. This differentiation of certain individuals so as to adapt them to special functions seems to me very remarkable; for it must be remembered that the difference is not one of age or sex.

The food of ants consists of insects—great numbers of which they destroy—of honey, honey-dew, and fruit; indeed, scarcely any animal or sweet substance comes amiss to them. Some species—such, for instance, as the small brown garden ant—ascend bushes in search of aphides. The ant then taps the aphis gently with her antennæ, and the aphis emits a drop of sweet fluid, which the ant drinks. Sometimes the ants even build covered ways up to and over the aphides, which, moreover, they protect from the attacks of other insects. Our English ants do not collect provision for the winter—indeed, their food is not of a nature which would admit of this. Some southern species, however, collect grain, occasionally in considerable quantities. Moreover, though our English ants cannot be said exactly to lay up stores, some at least do take steps to provide themselves with food in the future. The small yellow meadow ant (*Lasius flavus*), for instance, lives principally on the honey-dew of certain aphides which suck the roots of grass. The ants collect the aphides in the nest, not only watching over them themselves, but, as I have been able to satisfy myself, even over their eggs—an act which one is much tempted to refer to forethought, and which in such a case implies a degree of prudence superior to that of some savages. Besides these aphides, many other insects live in ants' nests. If they are to be regarded as domestic animals, then ants have more domestic animals than we have. The majority of these ant-guests are beetles. Some of them—as, for instance, the curious little *Claviger*—are quite blind, and are only found in ants' nests, the ant taking just as much care of them as of their own young. It is evident, therefore, that in some way they are useful or agreeable to the ants. The subject, however, is one as yet but little understood, and very difficult to study. Grimm and Lespés consider that some of these beetles secrete a sweet fluid like the aphides, and from analogy this seems probable. Other creatures which habitually live in ants' nests, like the little *Beckia albinos* or the blind woodlouse (*Platyarthrus*), perhaps make themselves useful as scavengers.

Nor are ants without their enemies. In addition to birds and other larger foes, if you disturb a nest of the brown ants at any time during the summer, you will probably see some very small flies hovering over them, and every now and then making a dash at some particular ant. These flies belong to the genus *Phora*, and to a species hitherto unnamed, which Mr. Verrall has been good enough to describe for me. They lay their eggs on the ants, inside which

the larvæ live. Other species of the genus are in the same way parasitic on bees. On the 14th of October last I observed that one of my ants had a mite attached to the underside of its head. The mite, which is still in the same position, is almost as large as the head. The ant cannot remove it herself. She has never come out of the nest, so that I could not do it for her, and none of her own companions from that day to this have thought of performing this kind office.

In character the different species of ants differ very much from one another. *F. fusca*, the one which is preëminently the enslaved ant, is, as might be expected, extremely timid; while the nearly allied *F. cinerea* has, on the contrary, a considerable amount of individual audacity. *F. rufa*, the horse ant, according to M. Forel, is especially characterized by the want of individual initiative, and always moves in troops; he also regards the genus *Formica* as the most brilliant, though some others excel it in other respects, as, for instance, in the sharpness of their senses. *F. pratensis* worries its slain enemies; *F. sanguinea* never does. The slave-making ant (*P. rufescens*) is, perhaps, the bravest of all. If a single individual finds herself surrounded by enemies, she never attempts to fly, as any other ant would, but transfixes her opponents one after another, springing right and left with great agility, till at length she succumbs, overpowered by numbers. *M. scabrinodis* is cowardly and thievish; during wars among the larger species they haunt the battle-fields and devour the dead. *Tetramorium* is said to be very greedy; *Myrmecina* very phlegmatic.

In industry ants are not surpassed even by bees and wasps. They work all day, and in warm weather, if need be, even at night too. I once watched an ant from six in the morning, and she worked without intermission till a quarter to ten at night. I had put her to a saucer containing larvæ, and in this time she carried off no less than a hundred and eighty-seven to the nest. I once had another ant, which I employed in my experiments, under observation several days. When I came up to London in the morning, and went to bed at night, I used to put her in a small bottle, but the moment she was let out she began to work again. On one occasion I was away from home for a week. On my return I let her out of the bottle, placing her on a little heap of larvæ about three feet from the nest. Under these circumstances I certainly did not expect her to return. However, though she had thus been six days in confinement, the brave little creature immediately picked up a larva, carried it off to the nest, and after half an hour's rest returned for another.

We have had hitherto very little information as to the length of life in ants. So far, indeed, as the preparatory stages are concerned, there is little difficulty in approximately ascertaining the facts—namely, that while they take only a few weeks in summer, in some

species, as our small yellow meadow ants, the autumn larvæ remain with comparatively little change throughout the winter. It is much more difficult to ascertain the length of life of the perfect insect, on account of their gregarious habits, and the difficulty of recognizing individual ants. It has, however, generally been supposed that they live about a season, and this is probably the case; but I have still some workers of *F. cinerea*, which I captured at Castellamare in November, 1875, and some of *F. sanguinea* and *F. fusca* since September in that year. They must now, therefore, be at least a year and a half old. I have also some queens of *F. fusca* which have been with me since December, 1874, and still seem in perfect health. If they lived much longer, and could compare their experiences, ants would, from their immense numbers, even in temperate regions, contend with mankind on no such very unequal terms.

The behavior of ants to one another differs very much according as they are alone or supported by numerous companions. An ant which would run away in the first case, will fight bravely in the second.

It is hardly necessary to say that, as a general rule, each species lives by itself. There are, however, some interesting exceptions. The little *Stenamma Westwoodii* is found exclusively in the nests of the much larger *F. rufa* and the allied *F. pratensis*. We do not know what the relations between the two species are. The *Stenammas*, however, follow the *Formicas* when they change their nest, running about among them and between their legs, tapping them inquisitively with their antennæ, and even sometimes climbing on to their backs, as if for a ride, while the large ants seem to take little notice of them. They almost seem to be the dogs—or rather cats—of the ants. Another small species, *Solenopsis fugax*, which makes its chambers and galleries in the walls of the nests of larger species, is the bitter enemy of its hosts. The latter cannot get at them, because they are too large to enter the galleries. The little *Solenopsis*, therefore, are quite safe, and, as it appears, make incursions into the nurseries of the larger ant, and carry off the larvæ as food. It is as if we had small dwarfs, about eighteen inches to two feet long, harboring in the walls of our houses, and every now and then carrying off some of our children into their horrid dens.

Most ants, indeed, will carry off the larvæ and pupæ of others if they get a chance; and this explains, or at any rate throws some light upon, that most remarkable phenomenon, the existence of slavery among ants. If you place a number of larvæ and pupæ in front of a nest of the horse ant, for instance, they are soon carried off; and those which are not immediately required for food remain alive for some days, though I have never been able to satisfy myself whether they are fed by their captors. Both the horse ant and the slave ant (*F. fusca*) are abundant species, and it must not unfrequently occur that the former, being pressed for food, attack the latter and carry off

some of their larvæ and pupæ. Under these circumstances it occasionally happens that the pupæ come to maturity in the nests of the horse ant, and nests are sometimes, though rarely, found in which with the legitimate owners there are a few *F. fuscas*. With the horse ant this is, however, a very rare and exceptional phenomenon; but with an allied species, *F. sanguinea*, a species which exists in our southern counties and throughout Europe, it has become an established habit. The *F. sanguineas* make periodical expeditions, attack neighboring nests of *F. fusca*, and carry off the pupæ. When the latter come to maturity, they find themselves in a nest consisting partly of *F. sanguineas*, partly of *F. fuscas*—the results of previous expeditions. They adapt themselves to circumstances, assist in the ordinary household duties, and, having no young of their own species, feed and tend those of the *F. sanguinea*. But though the *F. sanguineas* are thus aided by the *F. fuscas*, they have not themselves lost the instinct of working. It seems not improbable that there is some division of functions between the two species, but we have as yet no distinct knowledge on this point, and at any rate the *F. sanguineas* can "do" for themselves, and carry on a nest, if necessary, without slaves.

In another species, however, *Polyergus rufescens*, which is not British, this is not the case. They present a striking lesson of the degrading tendency of slavery, for they have become entirely dependent on their slaves. Even their bodily structure has undergone a change: their mandibles have lost their teeth, and have become mere nippers—deadly weapons, indeed, but useless except in war. They have lost the greater part of their instincts: their art, that is, the power of building; their domestic habits, for they take no care of their own young, all this being done by the slaves; their industry—they take no part in providing the daily supplies; if the colony changes the situation of its nest, the masters are all carried by the slaves to the new one; nay, they have even lost the habit of feeding. Huber placed thirty of them, with some larvæ and pupæ, and a supply of honey, in a box.

"At first," he says, "they appeared to pay some little attention to the larvæ; they carried them here and there, but presently replaced them. More than one-half of the Amazons died of hunger in less than two days. They had not even traced out a dwelling, and the few ants still in existence were languid and without strength. I commiserated their condition, and gave them one of their black companions. This individual, unassisted, established order, formed a chamber in the earth, gathering together the larvæ, extricated several young ants that were ready to quit the condition of pupæ, and preserved the life of the remaining Amazons."[1]

This observation has been fully confirmed by other naturalists. However small the prison, however large the quantity of food, these

[1] Huber, "Natural History of Ants."

stupid creatures will starve in the midst of plenty rather than feed themselves. I have had a nest of this species under observation for a long time, but never saw one of the masters feeding. I have kept isolated specimens for weeks by giving them a slave for an hour or two a day to clean and feed them, and under these circumstances they remained in perfect health, while but for the slaves they would have perished in two or three days. I know no other case in Nature of a species having lost the instinct of feeding.

In *P. rufescens*, the so-called workers, though thus helpless and stupid, are numerous, energetic, and in some respects even brilliant. In another slave-making species, however, *Strongylognathus*, the workers are much less numerous, and so weak that it is an unsolved problem how they contrive to make slaves.

Lastly, in a fourth species, *Anergetes atratulus*, the workers are absent, the males and females living in nests with workers belonging to another ant, *Tetramorium cæspitum*. In these cases the *Tetramoriums*, having no queen, and consequently no young of their own, tend the young of the *Anergetes*. It is, therefore, a case analogous to that of *Polyergus*, but it is one in which slave-owning has almost degenerated into parasitism. It is not, however, a case of true parasitism, because the *Tetramoriums* take great care of the *Anergetes*, and, if the nest is disturbed, carry them off to a place of safety.

M. Forel, in his excellent work on ants, has pointed out that very young ants devote themselves at first to the care of the larvæ and pupæ, and that they take no share in the defense of the nest or other out-of-door work until they are some days old. This seems natural, because at first their skin is comparatively soft; and it would clearly be undesirable to undertake rough work or run into danger until their armor had had time to harden. There are, however, reasons for thinking that the division of labor is carried still further. I do not allude merely to those cases in which there are completely different kinds of workers, but even to the ordinary workers. In *L. flavus*, for instance, it seems probable that the duties of the small workers are somewhat different from those of the large ones, though no such division of labor has yet been detected. In *F. fusca* I made an observation which surprised me very much. In the autumn of 1875 I noticed an ant out feeding alone. The next day the same ant was out by herself, and I could easily recognize her because by some accident she had lost the claws of one of her hind-feet. My attention being roused, I watched the nest for some weeks, and saw this same ant out repeatedly, but no other. This winter I have kept two nests under close observation —that is, I arranged with my daughters and their governess, Miss Wendland, most conscientious observers, that we should look at the nest once every hour throughout the day, and this has been done since the middle of November, with a few exceptions not enough

to affect the conclusion. The former nest contains about two hundred, the second about four hundred individuals; but as they are somewhat torpid, and there are no larvæ to be fed, much food is not required. In each case only two or three individuals came out for food, each about twice a day, though some days they did not come out at all. Thinking that possibly these specimens were unusually voracious, or in some other way abnormal, I imprisoned the foragers belonging to one of the nests. The following day two others came out for food, and continued coming for several days. I then imprisoned them also, when two others came out—showing, I think, that the community requires food, and that it was the functions of certain individuals to obtain it.

One of the most interesting problems about ants is, of course, to determine the amount of their intelligence. In order to test this, it seemed to me that one way would be to ascertain some object which they would clearly desire, and then to interpose some obstacle which a little ingenuity would enable them to overcome. With this object in view, I placed food in a porcelain cup on a slip of glass surrounded by water, but accessible to the ants by a bridge, consisting of a strip of paper two-thirds of an inch long and one-third wide. Having then put a *F. nigra* from one of my nests to this food, she began carrying it off, and by degrees a number of friends came to help her. I then, when about twenty-five ants were so engaged, moved the little paper bridge slightly, so as to leave a chasm just so wide that the ants could not reach across. They came to the edge and tried hard to get over, but it did not occur to them to push the paper bridge, though the distance was only about one-third of an inch, and they might easily have done so. After trying for about a quarter of an hour they gave up the attempt, and returned home. This I repeated several times. Then, thinking that paper was a substance to which they were not accustomed, I tried the same with a bit of straw one inch long and one-eighth of an inch wide. The result was the same. I repeated this twice. Again I placed particles of food close to and directly over the nest, but connected with it only by a passage several feet in length. Under these circumstances it would be obviously a saving of time and labor to drop the food on to the nest, or at any rate to spring down with it, so as to save one journey. But, though I have frequently tried the experiment, my ants never adopted either of these courses. I arranged matters so that the glass on which the food was placed was only raised one-third of an inch above the nest. The ants tried to reach down, and the distance was so small that occasionally, if another ant passed underneath just as one was reaching down, the upper one could step on to its back, and so descend; but this only happened accidentally, and they did not think of throwing the particles down, nor, which surprised me very much, would they jump down themselves.

I then placed a heap of fine mould close to the grass, but just so far that they could still not reach across. It would have been of course quite easy for any ant, by moving a particle of earth for a quarter of an inch, to have made a bridge by which the food might have been reached, but this simple expedient did not occur to them. On the other hand, I then put some provisions in a shallow box with a glass top, and a single hole on one side, and put some specimens of *Lasius niger* to the food. As soon as a stream of ants was at work, busily carrying supplies off to the nest, and when they had got to know the way thoroughly, I poured some fine mould in front of the hole so as to cover it up to a depth of about half an inch. I then took out the ants which were actually in the box. As soon as they had recovered from the shock of this unexpected proceeding on my part, they began to run all around and about the box, looking for some other place of entrance. Finding none, however, they began digging down into the earth just over the hole, carrying off the grains of earth one by one, and depositing them, without any order, all round at a distance of from half an inch to six inches, until they had excavated down to the doorway, when they again began carrying off the food as before. This experiment I repeated on the following days three or four times, always with the same result.

As evidence both of their intelligence and of their affection for their friends, it has been said by various observers that when ants have been accidentally buried they have been very soon dug out and rescued by their companions. Without for a moment doubting the facts as stated, we must remember the habits which ants have of burrowing in loose fresh soil, and especially their practice of digging out fresh galleries when their nests are disturbed. It seemed to me, however, that it would not be difficult to test whether the excavations made by ants under the circumstances were the result of this general habit, or really due to a desire to extricate their friends. With this view I tried (20th of August) the following experiments: I placed some honey near a nest of *Lasius niger* on a glass surrounded with water, and so arranged that in reaching it the ants passed over another glass covered with a layer of sifted earth about one-third of an inch in thickness. I then put some ants to the honey, and by degrees a considerable number collected round it. Then, at 1.30 P. M., I buried an ant from the same nest under the earth, and left her there till 5 P. M., when I uncovered her. She was none the worse, but during the whole time not one of her friends had taken the least notice of her.

Again, September 1st, I arranged some honey in the same way. At 5 P. M. about fifty ants were at the honey, and a considerable number were passing to and fro. I then buried an ant as before, of course taking one from the same nest. At 7 P. M. the number of ants at the honey had nearly doubled. At 10 P. M. they were still

more numerous, and had carried off about two-thirds of the honey. At 7 A. M. the next morning the honey was all gone; two or three ants were still wandering about, but no notice had been taken of the prisoner, whom I then let out. In this case I allowed the honey to be finished, because I thought it might perhaps be alleged that the excitement produced by such a treasure distracted their attention; or even, on the principle of doing the greatest good to the greatest number, that they were intelligently wise in securing a treasure of food before they rescued their comrade, who, though in confinement, was neither in pain nor danger. So far as the above ants, however, are concerned, this cannot be urged. I may add that I repeated the same experiment several times, in some cases with another species, *Myrmica ruginodis*, and always with the same results.

Ants have been much praised on account of their affection for their friends. In this respect, however, they seem to vary greatly. At any rate, any one who has watched them much must have met with very contradictory facts. I have often put ants which were smeared with a sticky substance on the boards attached to my nests, and very rarely indeed did their companions take any notice of or seek to disentangle them.

I then tried the following experiment: A number of the small yellow ants (*L. flavus*) were out feeding on some honey. I took five of them, and also five others of the same species, but from a different nest, chloroformed them, and put them close to the honey, and on the path which the ants took in going to and from the nest, so that these could not but see them. The grass on which the honey was placed was surrounded by a moat of water. This, then, gave me an opportunity of testing both how far they would be disposed to assist a helpless fellow-creature, and what difference they would make between their nest-companions and strangers from a different community. The chloroformed ants were put down at ten in the morning. For more than an hour, though many ants came up and touched them with their antennæ, none of them did more. At length one of the strangers was picked up, carried to the edge of the glass, and quietly thrown, or rather dropped, into the water. Shortly afterward a friend was taken up and treated the same way. By degrees they were all picked up and thrown into the water. One of the strangers was, indeed, taken into the nest, but in about half an hour she was brought out again and thrown into the water like the rest. I repeated this experiment with fifty ants, half friends and half strangers. In each case twenty out of the twenty-five ants were thrown into the water as described. A few were left lying where they were placed, and these also, if we had watched longer, would no doubt have been also treated in the same way. One out of the twenty-five friends, and three out of the twenty-five strangers, were carried into the nest, but they were all brought out

again and thrown away like the rest. Under such circumstances, then, it seems that ants make no difference between friends and strangers.

It may, however, be said in this experiment that, as ants do not recover from chloroform, and these ants were therefore to all intents and purposes dead, we should not expect that much difference would be made between friends and strangers. I therefore tried the same experiment, only, instead of chloroforming the ants, I made them intoxicated. This was a rather more difficult experiment. No ant would voluntarily degrade herself by getting drunk, and it was not easy in all cases to hit off the requisite degree of this compulsory intoxication. In all cases they were made quite drunk, so that they lay helplessly on their backs. The sober ants seemed much puzzled at finding their friends in this helpless and discreditable condition. They took them up and carried them about for a while in a sort of aimless way, as if they did not know what to do with their drunkards, any more than we do. Ultimately, however, the results were as follows: The ants removed twenty-five friends and thirty strangers. Of the friends, twenty were carried into the nest, where no doubt they slept off the effect of the spirit—at least, we saw no more of them—and five were thrown into the water. Of the strangers, on the contrary, twenty-four were thrown into the water; only six were taken into the nest, and four of these were shortly afterward brought out again and thrown away.

The difference in the treatment of friends and strangers was, therefore, most marked.

Dead ants, I may add, are always brought out of the nest, and I have more than once found a little heap on one spot, giving it almost the appearance of a burial-ground.

I have also made some experiments on the power possessed by ants of remembering their friends. It will be recollected that Huber gives a most interesting account of the behavior of some ants, which, after being separated for four months, when brought together again, immediately recognized one another, and "fell to mutual caresses with their antennæ." Forel, however, regards these movements as having indicated fear and surprise rather than affection, though he also is quite inclined to believe, from his own observation, that ants would recognize one another after a separation of some months. The observation recorded by Huber was made casually; and neither he nor any one else seems to have taken any steps to test it by subsequent experiments. The fact is one, however, of so much interest, that it seemed to me desirable to make further experiments on the subject. On the 4th of August, 1875, therefore, I separated one of my nests of *F. fusca* into two halves, which I kept entirely apart.

I then from time to time put an ant from one of these nests into the other, introducing also a stranger at the same time. The stranger

was driven out, or sometimes even killed. The friend, on the contrary, was never attacked, though I am bound to say that I could see no signs of any general welcome, or that she was taken any particular notice of.

I will not trouble you with all the evidence, but will content myself with one case.

On the 12th November last—that is to say, after the ant had been separated for a year and three months—I put a friend and a stranger into one of the divisions. The friend seemed quite at home. One of the ants at once seized the stranger by an antenna, and began dragging her about. At—

11.45.—The friend is quite at home with the rest. The stranger is being dragged about.

12.—The friend is all right. Three ants now have hold of the stranger by her legs and an antenna.

12.15.—Do. do.

12.30.—Do. do.

12.45.—Do. do.

1.—Do. do.

1.30.—Do. One now took hold of the friend, but soon seemed to find out her mistake and let go again.

1.45.—The friend is all right. The stranger is being attacked. The friend also has been almost cleaned; while on the stranger the color has been scarcely touched.

2.15.—Two ants are licking the friend, while another pair are holding the stranger by her legs.

2.30.—The friend is now almost clean, so that I could only just perceive any color. The stranger, on the contrary, is almost as much colored as ever. She is now near the door, and I think would have come out, but two ants met her and seized her.

3.—Two ants are attacking the stranger. The friend was no longer distinguishable from the rest.

3.30.—Do.

4.—Do.

5.—Do.

6.—The stranger now escaped from the nest, and I put her back among her own friends.

The difference of behavior to these two ants was most marked. The friend was gradually licked clean, and, except for a few moments, and that evidently by mistake, was never attacked. The stranger, on the contrary, was not cleaned, was at once seized, was dragged about for hours with only a few minutes' interval, by one, two, or three assailants, and at length made her escape from the nest at a time when no other ant was out.

In most species of ants the power of smell is very keen. I placed ants on a strip of paper, each end of which was supported on a pin,

the foot of which was immersed in water. They then ran backward and forward along the paper, trying to escape. If a camel's-hair pencil be suspended just over the paper, they pass under it without taking any notice of it; but if it be scented, say with lavender-water, they at once stop when they come near it, showing in the most unmistakable manner that they perceive the odor. This sense appears to reside, though not perhaps exclusively, in the antennæ. I tethered, for instance, a large specimen of *Formica ligniperda* with a fine thread to a board, and when she was quite quiet I approached a scented camel's-hair pencil slowly to the tip of the antenna, which was at once withdrawn, though the antenna took no notice of a similar pencil, if not scented.

On the other hand, as regards their sense of hearing, the case is very different. Approaching an ant which was standing quietly, I have over and over again made the loudest and most shrill noises I could, using a penny pipe, a dog-whistle, a violin, as well as the most piercing and startling sounds I could produce with my own voice, without effect. At the same time I by no means would infer from this that they are really deaf, though it certainly seems that their range of hearing is very different from ours. We know that certain allied insects produce a noise by rubbing one of their abdominal rings against another. Landois is of opinion that ants also make sounds in the same way, though these sounds are inaudible to us. Our range is, however, after all, very limited, and the universe is probably full of music which we cannot perceive. There are, moreover, in the antennæ of ants certain curious organs which may perhaps be of an auditory character. There are from ten to a dozen in the terminal segment of *Lasius flavus*, the small meadow ant, and, indeed, in most of the species which I have examined, and one or two in each of the short intermediate segments. These organs consist of three parts: a small, spherical cup opening to the outside, a long, narrow tube, and a hollow body shaped like an elongated clock-weight. They may serve to increase the resonance of sounds, acting, in fact, to use the words of Prof. Tyndall, who was good enough to look at them with me, like microscopic stethoscopes.

The organs of vision are in most ants very complex and conspicuous. There are generally three eyes arranged in a triangle on the top of their heads, and on each side a large compound eye containing sometimes more than two thousand facets between them. Nevertheless, the sight of ants does not seem to be very good. In order to test how far ants are guided by vision, I made the following experiments: I placed a common lead-pencil on a board, fastening it upright, so as to serve as a landmark. At the base I then placed a glass containing food, and then put a *L. niger* to the food; when she knew her way from the glass to the nest and back again perfectly well, she went quite straight backward and forward. I then took an oppor-

tunity when the ant was on the glass, and moved the glass with the ant on it about three inches. Now, under such circumstances, if she had been much guided by sight, she could not of course have had any difficulty in finding her way to the nest. As a matter of fact, however, she was entirely at sea, and, after wandering about for some time, got back to the nest by another and very round-about route. I then again varied the experiment as follows: I placed the food in a small china cup on the top of the pencil, which thus formed a column seven and a half inches high. When the ant once knew her way, she went very straight to and from the nest. This puzzled her very much; she went over and over the spot where the pencil had previously stood, retraced her steps several times almost to the nest, and then returned along the old line, showing great perseverance, if not much power of vision. I then moved the pencil six inches. She found the pencil at last, but only after many meanderings.

I then repeated the observation on three other ants, with the same result; the second was seven minutes before she found the pencil, and at last seemed to do so accidentally; the third actually wandered about for no less than half an hour, returning up the paper bridge several times.

Let us compare this relatively to man. An ant measuring say one-sixth of an inch, the pencil, being seven inches high, is consequently forty-two times as long as the ant. It bears, therefore, somewhat the same relation to the ant as a column two hundred and fifty feet high does to a man. The pencil having been moved six inches, it is as if a man in a country he knew well would be puzzled at being moved a few hundred feet, or, if put down in a square containing less than an acre, could not find a column two hundred and fifty feet high, that is to say, higher than the Duke of York's column.

Another evidence of this consists in the fact that if, when my *L. nigers* were carrying off food placed in a cup on a piece of board, I turned the board round so that the side which had been turned toward the nest was away from it, and *vice versa*, the ants always returned over the same track on the board, and consequently directly away from home. If I moved the board to the other side of my artificial nest, the result was the same. Evidently they followed the road, not the direction.

It is remarkable that we do not even now know exactly how an ants' nest is begun. Whether they always commence as a colony from some older establishment; whether wandering workers who chance to find a queen under certain circumstances remain with her and begin a new nest; or whether the queen ant, like the queen wasp, forms a cell for herself, and then brings up a few workers, who afterward take upon themselves the labors of the family, as yet we know not. When once started, the communities last for years, being kept up by a succession of individuals. The queens themselves

rarely or never quit the nest, but receive their food from the workers, and indeed appear to do nothing except lay eggs.

A nest of ants must not be confused with an ant-hill in the ordinary sense. Very often, indeed, a nest has only one dwelling, and in most species seldom more than three or four. Some, however, form numerous colonies. M. Forel even found a case in which one nest of *F. exsecta* had no less than two hundred colonies, and occupied a circular space with a radius of nearly two hundred yards. Within this area they had exterminated all the other ants, except a few nests of *Tapinoma erraticum*, which survived, thanks to their great agility. In these cases the number of ants thus associated together must have been enormous. Even in single nests Forel estimates the numbers at from 5,000 to 500,000.

In their modes of fighting, different species of ants have their several peculiarities. Some, also, are much less military than others. *Myrmecina Latreillii*, for instance, never attack, and scarcely even defend themselves. Their skin is very hard, and they roll themselves into a ball, not defending themselves even if their nest is invaded; to prevent which, however, they make the entrances small, and often station at each a worker, who uses her head to stop the way. The smell of this species is also, perhaps, a protection. *Tetramorium cæspitum* has the habit of feigning death. This species, however, does not roll itself up, but merely applies its legs and antennæ closely to the body.

Formica rufa, the common horse ant, attacks in serried masses, seldom sending out detachments, while single ants scarcely ever make individual attacks. They rarely pursue a flying foe, but give no quarter, killing as many enemies as possible, and never hesitating, with this object, to sacrifice themselves for the common good.

Formica sanguinea, on the contrary, at least in their slave-making expeditions, attempt rather to terrify than to kill. Indeed, when they are invading a nest, they do not attack the flying inhabitants unless they are attempting to carry off pupæ, in which case they are forced to abandon the pupæ. When fighting, they attempt to crush their enemies with their mandibles.

Formica exsecta is a delicate but very active species. They, also, advance in serried masses, but in close quarters they bite right and left, dancing about to avoid being bitten themselves. When fighting with larger species they spring on to their backs, and then seize them by the neck or by an antenna. They also have the instinct of combining in small parties, three or four seizing an enemy at once, and then pulling different ways, so that she, on her part, cannot get at any one of her foes. One of them then jumps on her back and cuts, or rather saws, off her head. In battles between this ant and the much larger *F. pratensis*, many of the latter may be seen, each with a little *F. exsecta* on her back, sawing off her head from behind.

One might, at first sight, be disposed to consider that the ants with stings must have a great advantage over those with none. In some cases, however, the poison is so strong that it is sufficient for it to touch the foes to place them *hors de combat*, or at least to render them incapacitated, with every appearance of extreme pain. Such species have the abdomen unusually mobile.

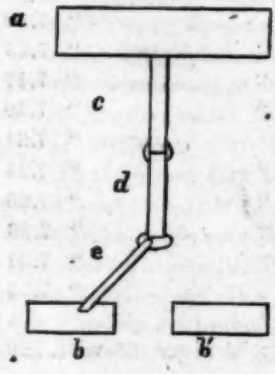
The species of *Lasius* make up in numbers what they want in strength. Several of them seize an enemy at once, one by each of her legs or antennæ, and, when they have once taken hold, they will suffer themselves to be cut in pieces rather than let go.

Polyergus rufescens, the celebrated slave-making or Amazon ant, has a mode of combat almost peculiar to herself. The jaws are very powerful and pointed. If attacked — if, for instance, another ant seizes her by a leg—she at once takes her enemy's head into her jaws, which generally makes her quit her hold. If she does not, the *Polyergus* closes her mandibles, so that the points pierce the brain of her enemy, paralyzing the nervous system. The victim falls in convulsions, setting free her terrible foe. In this manner a comparatively small force of *Polyergus* will fearlessly attack much larger armies of other species, and suffer themselves scarcely any loss.

Much of what has been said as to the powers of communication possessed by bees and ants depends on the fact that, if one of them in the course of her rambles has discovered a supply of food, a number of others soon find their way to the store. This, however, does not necessarily imply any power of describing localities. If the bees or ants merely follow their more fortunate companion, or if they hunt her by scent, the matter is comparatively simple; if, on the contrary, the others have the route described to them, the case becomes very different. To determine this, therefore, I have made a great number of experiments, of which, however, I will here only mention a few. Under ordinary circumstances, if an ant discovers a stock of food, she carries as much as possible away to the nest, and then returns for more, accompanied generally by several friends. On their return, these bring others, and; in this way, a string of ants is soon established. Unless, therefore, various precautions are taken—and this, so far as I know, has never been done in any of the previous observations—the experiment really tells very little.

I therefore made the following arrangement: One of my nests of the small brown garden ant, *Lasius niger*, was connected with a board, on which I was in the habit of placing a supply of food and water. At a short distance from the board I placed two glasses (*b b'*), and on *b* I placed some food. I then connected the glass *b* with the board *a* by three slips of paper, *c*, *d*, *e*, and put an ant to the food. She carried off a supply to the nest, returning for more, and so on. Several friends came with her, and I imprisoned them till the experiment was over. When she had passed several times over the

paper bridges, I proceeded as follows: Any friends who came with her were excluded from the bridges when she was on them. If she was not there, as soon as a friend arrived at the bridge *c*, I took up *e* in my fingers and rubbed it lightly, with a view of removing or blurring the scent; and as soon as the ant arrived on *d* I took up the bridge *c*, and put it across the chasm from *d* to *b'*. Now, if the ant went by description, she would of course cross *e* to *b*. If, on the



other hand, she went by scent, then she would be at the least as likely to go over *c* to *b'*. The results were that, out of about one hundred and twenty friends who passed over *d*, only twenty went to the food, while nearly one hundred passed over *c* to the empty glass. In this case the friends generally came more or less in sight of one another to the bridge *c*, and, once there, could hardly avoid arriving either at *b* or *b'*. I therefore modified the experiment as follows: I established and endowed an ant as before, imprisoning the friends who came with her. When she got to know her way thoroughly, I allowed her to return to the nest on her own legs, but as soon as she emerged again I took her up and transferred her to the food.

Under these circumstances, as will be seen, very few ants indeed ever found their way to the food. I began this at 5.30, when she returned to the nest. At 5.34 she came out with no less than ten friends, and was then transferred to the food. The others wandered about a little, but by degrees returned to the nest, not one of them finding her way to the food. The first ant took some food, returned, and again came out of the nest at 5.39 with eight friends, when exactly the same happened. She again came out—

At 5.44	with	4	friends.	At 6.44	with	0	friends.
" 5.47	"	4	"	" 6.46	"	3	"
" 5.49	"	1	"	" 6.49	"	2	"
" 5.52				" 6.56			
" 5.54	"	5	"	" 6.59			
" 5.58	"	2	"	" 7.2	"	2	"
" 5.59	"	2	"	" 7.4			
" 6.1	"	5	"	" 7.6	"	3	"
" 6.4	"	1	"	" 7.8	"	3	"
" 6.7				" 7.10	"	5	"
" 6.11	"	3	"	" 7.13			
" 6.14	"	4	"	" 7.17	"	3	"
" 6.17	"	6	"	" 7.19	"	7	"
" 6.20				" 7.21	"	5	"
" 6.23	"	5	"	" 7.24			
" 6.25	"	6	"	" 7.26	"	3	"
" 6.29	"	8	"	" 7.29	"	1	"
" 6.32	"	2	"	" 7.31	"	2	"
" 6.35				" 7.35			
" 6.42	"	4	"				

(39 journeys: 11 alone, 28 with 120 friends.)

Thus, during these two hours, more than one hundred and twenty ants came out of the nest, in company with the one under observation. She knew her way perfectly, and it is clear that, if she had been left alone, all these ants would have accompanied her to the store of food. Three of them were accidentally allowed to do so, but of the remainder only five found their way to the food; all the others, after wandering about awhile, returned empty-handed to the nest.

I conclude, then, that when large numbers of ants come to food they follow one another, being also to a certain extent guided by scent. The fact, therefore, does not imply any considerable power of intercommunication. There are, moreover, some circumstances which seem to point in an opposite direction. For instance, I have already mentioned that if a colony of *Polyergus* changes the situation of its nest, the masters are all carried to the new one by the slaves. Again, if a number of *F. fusca* are put in a box, and in one corner a dark place of retreat is provided for them with some earth, one soon finds her way to it. She then comes out again, and, going up to one of the others, takes her by the jaws. The second ant then rolls herself into a heap, and is carried off to the place of shelter. They then both repeat the same manœuvre with other ants, and so on until all their companions are collected together. Now, it seems to me difficult to imagine that so slow a course would be adopted if they possessed any power of communicating description.

On the other hand, they certainly can, I think, transmit simpler

ideas. In support of this I may adduce the following experiment: Two strips of paper were attached to the board just mentioned (p. 54), and parallel to one another, and at the other end of each I placed a piece of glass. In the glass at the end of one tape I placed a considerable number (three to six hundred) of larvæ. In the second I put two or three larvæ only. I then took two ants, and placed one of them to the glass with many larvæ, the other to that with two or three. Each of them took a larva and carried it to the nest, returning for another, and so on. After each journey I put another larva in the glass with only two or three larvæ, to replace that which had been removed. Now, if other ants came under the above circumstances as a mere matter of accident, or accompanying one another by chance, or if they simply saw the larvæ which were being brought, and consequently concluded that they might themselves also find larvæ in the same place, then the numbers going to the two glasses ought to be approximately equal. In each case the number of journeys made by the ants would be nearly the same; consequently, if it were a matter of smell, the two routes would be in the same condition. It would be impossible for an ant, seeing another in the act of bringing a larva, to judge for itself whether there were few or many larvæ left behind. On the other hand, if the strangers were brought, then it would be curious to see whether more were brought to the glass with many larvæ than to that which only contained two or three. I should also mention that every stranger was imprisoned until the end of the experiment. I will select a few of the results:

Experiment 1.—Time occupied, one hour. The ant with few larvæ made six visits, and brought no friends. The one with many larvæ made seven, and brought eleven friends.

Experiment 3.—Time occupied, three hours. The ant with few larvæ made twenty-four journeys, and brought five friends. The one with many larvæ made thirty-eight journeys, and brought twenty-two friends.

Experiment 5.—Time occupied, one hour. The ant with few larvæ made ten journeys, and brought three friends. The other made five journeys, and brought sixteen friends.

Experiment 9.—Time occupied, one hour. The ant with few larvæ made eleven journeys, and brought one friend. The one with many larvæ made fifteen journeys, and brought thirteen friends.

Experiment 10.—I now reversed the glasses, the same two ants being under observation; but the ant which in the previous observation had few larvæ to carry off now consequently had many, and *vice versa*. Time occupied, two hours. The ant with few larvæ made twenty-one journeys, and brought one friend. The one with many larvæ made twenty-two journeys, and brought twenty friends. These two experiments are, I think, especially striking.

Taken as a whole, I found that in about fifty hours the ants which

had access to many larvæ brought two hundred and fifty-seven friends, while those visiting a glass with few larvæ only brought eighty-two. The result will appear still more striking if we remember that a certain number, say perhaps twenty-five, would have come to the larvæ anyhow, which would make the numbers two hundred and thirty-two as against fifty-seven, a very striking difference.

I have elsewhere discussed the relations of flowers to insects, and especially with bees, and particularly the mode in which the flowers were modified so that the bees might transfer the pollen from one flower to another. Ants are also of considerable importance to plants, especially in keeping down the number of insects which feed on them. So far as I know, however, there are no plants which are specially modified in order to be fertilized by ants; and, indeed, even to those small flowers which any little insect might fertilize, the visits of winged insects are much more advantageous, because, as Mr. Darwin has shown in his excellent work on cross and self fertilization of plants, it is important that the pollen should be brought, not only from a different flower, but also from a different plant, while creeping insects, such as ants, would naturally pass from flower to flower of the same plant.

Under these circumstances it is important to plants that ants should not obtain access to the flowers, for they would otherwise rob them of their honey without conferring on them any compensating advantage. Accordingly, we not only find in flowers various modes of attracting bees, but also of excluding ants; and in this way ants have exercised more influence on the vegetable kingdom than might be supposed. Sometimes, for instance, the flowers are protected by *chevaux-de-frise* of spines and fine hairs pointing downward (*Carlina*, *Lamium*); some have a number of glands secreting a glutinous substance, over which the ants cannot pass (*Linnæa*, gooseberry); in others the tube of the flower is itself very narrow, or is almost closed either by hairs or by internal ridges, which just leave space for the proboscis of a bee, but no more. Lastly, some, and especially pendulous flowers (*Cyclamen*, snowdrop), are so smooth and slippery that ants cannot easily enter them, but often slip off in the attempt, and thus are excluded, just as the pendulous nests of the weaver-birds preclude the entrance of snakes. This, however, is a large subject, into which I cannot now enter.

Let me, in conclusion, once more say that, as it seems to me, notwithstanding the labors of those great naturalists to whom I gratefully referred in commencing, there are in natural history few more promising or extensive fields for research than the habits of ants.—*Fortnightly Review.*

THE NEW STAR IN THE CONSTELLATION OF THE SWAN.[1]

By AMÉDÉE GUILLEMIN.

THE phenomenon of a new star appearing in the heavens is sufficiently rare to strike the imagination of the public, as well as to attract the attention of scientific men. On the one side, it possesses all the interest which attaches to the unexpected, to the mysterious unknown; and, on the other, it raises some very important questions as to the physical and chemical constitution of the stars, and as to the likeness between those distant suns and our own. But now more than ever before, more even than in the first moiety of the nineteenth century, is such curiosity justified, inasmuch as the new means of investigation in the hands of astronomers give promise of revealing, at least in a great measure, the nature of the strange transformations which give rise to these apparitions.

Before we consider the quite recent discovery made by Julius Schmidt, director of the observatory at Athens, let us make a brief review of the apparitions which preceded it.

Every one has seen in works on astronomy the account of the famous temporary star of 1572, which appeared during the month of November in the constellation of Cassiopeia, all of whose phases were observed by Tycho Brahe. Its extraordinary scintillation; its brightness, equaling and surpassing Vega, Jupiter, Sirius, and even Venus when in quadrature, so that it was visible at high noon; finally, its sudden diminution and disappearance after seventeen months of visibility, all conspired to give to this star an extraordinary celebrity.

In 1600 a new star appeared in the Swan, and was studied by Kepler; then it disappeared in 1621, was again visible in 1655, and at sundry times afterward; it is still visible.

Thirty years after the disappearance of the new star in Cassiopeia appeared the star in Serpentarius discovered by Brunowski in October, 1604, and which had for its observer and historian the great Kepler. It was visible for eighteen months, and, while it did not equal in brightness the star of 1572, it surpassed the stars of first magnitude, and even Jupiter itself.

In 1670 a third temporary star was discovered by the Carthusian Anthelme, in that part of the constellation of the Fox which is nearest to β of the Swan. At the time of its apparition, or rather of its discovery, June 20th, it was of the third magnitude. About August 10th it was only of the fifth magnitude, and three months later it disappeared, reappearing on March 17, 1671, with the lustre of a star of

[1] Translated from the French by J. Fitzgerald, A. M.

the fourth magnitude. The temporary stars of 1572 and 1604 had directed the attention of astronomers to the variableness of the light of stars; and already, in 1650, Bouillaud had approximately determined the period of Mira Ceti, or the star o in the constellation of the Whale. Cassini, who observed sensible variations in the star of the Fox, supposed that its period could be fixed at ten months; but it was sought for in vain in February, 1672; it did not reappear till the end of March, being at that time of the sixth magnitude; then it disappeared once more, and has since never been seen.

Between the star of the Fox and the star discovered on April 28, 1848, by Hind in Ophiuchus (or Serpentarius), 177 years elapsed. The star of 1848, which was of a dark yellow or reddish color, did not exceed the fifth magnitude, but the variations of its light were carefully studied during the whole period of its visibility. In 1850 it was hardly of the eleventh magnitude, and this magnitude it has since kept.

Here we may refer to the researches made since Cassini's time into ancient writings, whether European or Chinese, which show that many similar apparitions of new stars have been noted in chronicles and afterward forgotten: for instance, the star of the year 125 B. C., observed by Hipparchus, as we learn from Pliny; another, which appeared in the Emperor Hadrian's time; the new star seen in the constellation of the Eagle in the year 389, and which possessed a brilliancy resembling that of Venus; that seen in the Scorpion in the ninth century; the new stars of the years 945 and 1264, both of which made their appearance in very nearly the same part of the heavens between Cepheus and Cassiopeia.

Before we come to the two latest temporary stars, which have succeeded each other in an interval of ten and a half years, and which are worthy of a detailed description, let us briefly state the questions to which these apparitions have given rise among astronomers, and the hypotheses which have been offered for their solution.

To what causes must we refer the nearly always sudden apparitions of these strange bodies, their variations of lustre, their intermittence, as also their changes of color? Why is it that, after alternations of great lustre and of paling, their light gradually faded away, and what is the cause of their ultimate disappearance?

A thousand conjectures have been made in the effort to answer this question. Among the weightiest of these, the one which compares temporary stars to variable periodic stars must be rejected at once—not on the ground that these two classes of stars are absolutely distinct, but because the periodicity being due, either to a movement of rotation or to occultation on the one hand, or to a phenomenon peculiar to the star itself on the other, the first hypothesis is clearly inadmissible for the explanation of new stars, and the second is precisely the question to be solved.

Tycho Brahe, struck with the suddenness of the appearance of the star of 1572, and its position on the edge of the Milky-Way, offered a bold hypothesis which is now abandoned. He believed in a creation, or at least in the spontaneous incandescence of the nebulous matter of which he supposed the Milky-Way to be composed: when the new star vanished, the place it had occupied was void, or at least Brahe saw, in the absence of nebulosity at that spot, the result of the condensation of the matter the combustion of which had produced an appearance resembling a star. Humboldt justly compares this view, which at all events was an ingenious one, with the views held by W. Herschel as to the transformation of nebulæ into stellar masses. In Tycho Brahe's time it was not known that the light of the Milky-Way results from the aggregation of an indefinite number of stars, or stellar masses, and that it is within this immense agglomeration and in its vicinity that the nebulæ properly so called are rarest.

Besides, it has been proved that the stars known as "new" stars are anything but new. In the spot where the star of Ophiuchus made its appearance in 1848, there had previously been a star, noted by Lalande in Fortin's "Atlas Céleste" as a vanished star. So, too, the new star which appeared in May, 1866, in the Corona Borealis, and which at the start reached the second magnitude, had been already set down in catalogues as a star of the ninth magnitude; it still possesses the same lustre it had before it underwent, during the six months of its apparition, the extraordinary augmentation which attracts to it the attention of astronomers. Hence astronomers no longer believe in the creation or in the destruction of these stars. Before the sudden incandescence which makes them visible, they occupied the same places, and there they still remain after their more or less perfect extinction. It remains to inquire into the physical causes which produce these variations of lustre.[1]

Spectrum analysis has provided the first positive elements for the solution of this problem. As late as the year 1848 this method was as yet unknown; but when in 1866 the variable star of the Northern Crown (*Corona Borealis*) appeared, spectrum analysis was already so developed as to be profitably applied to the observation of it. The results obtained by Huggins and Miller in these researches were as follows:

[1] It is worth while to observe the ease with which these knotty questions are disposed of by persons who are wont to invoke supernatural agencies. Here is an instance dating from the seventeenth century, but similar instances may be found in our own time: Father Riccioli, as an explanation of the appearance of secondary stars, suggested the idea that some stars are luminous on one side; and whenever God would "exhibit to men some extraordinary sign, he turns toward them the luminous side (previously turned away from the earth) by causing the star to revolve about suddenly, either by the agency of some intelligent being, or in virtue of some faculty inherent in the star itself; then, by making another similar revolution, it suddenly vanishes, or pales gradually, like the moon in its phases." The explanation offered by the learned Jesuit is both ingenious and convenient. But, unfortunately, astronomers nowadays are not satisfied with it.

"The spectrum of the variable star of Corona Borealis is found to consist of two superposed spectra, the one made up of four bright lines, and the other resembling the solar spectrum, each resulting from the decomposition of a group of luminous rays independent of the light which produces the other. The continuous spectrum, furrowed with groups of dark rays, indicates the presence of a photosphere of incandescent matter, almost certainly solid or liquid, and surrounded by an atmosphere of cooler vapors, which produce by absorption the groups of darker lines. So far the constitution of this star resembles that of the sun; but it offers an additional spectrum composed of bright lines. Here, then, is a second source of special light, and this source must *be a luminous gas*. Furthermore, the two principal bright lines of this spectrum show that this gas consisted mainly of hydrogen; and their great brightness proves that the temperature of the luminous gas was higher than that of the photosphere. These facts, taken in connection with the suddenness of the outburst of light in the star, its im-

FIG. 1.—SPECTRUM OF THE VARIABLE STAR IN CORONA BOREALIS. (From Huggins and Miller.)

mediate and rapid diminution of brightness, and its decline, in the course of twelve days, from the second to the eighth magnitude, lead us to the conclusion that the star was suddenly enveloped in hydrogen-flames. Possibly it was the scene of some mighty convulsion, with disengagement of an enormous amount of liberated gas. A great portion of this gas was hydrogen, which burned on the surface of the star by combining with some other element. The light given forth by this flaming gas was characterized by the spectrum with bright lines. The spectrum of the other portion of the star's light probably showed that this terrible conflagration of gas had surcharged and rendered more vividly incandescent the solid matter of the photosphere. When the free hydrogen had been exhausted, the flame died away by degrees, the photosphere became less luminous, and the star returned to its former state. . . . We must not forget," adds Mr. Huggins, "that light, though it travels with such great velocity, nevertheless requires a certain time to come to us from the star. Hence this grand physical convulsion, though new to us, was a thing of the past as regards the star itself. In 1866 the star had already for years been in the new conditions produced by this violent catastrophe."

The solar protuberances had not as yet been directly analyzed in 1866; it was not yet known that a continuous stratum of incandescent hydrogen envelops the bright photosphere of the sun, and that the emission of this gas, in the form of irregular jets, undergoes in the sun variations, phases, which are at least so far related to the sun-spots as to be coincident with them. What mighty physical revolu-

tion was it that suddenly produced the incandescence of the sun of the Corona, transforming it from a star of the ninth to one of the second magnitude?

What would become of our planet were such a revolution as this to take place in the sun, and were the calorific and luminous radiation to be suddenly increased a hundred-fold?

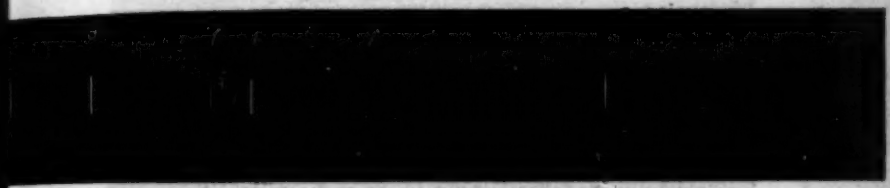


FIG. 2.—SPECTRUM OF THE NEW STAR IN THE CONSTELLATION OF THE SWAN. (From Cornu.)

But let us come to the new star of the Swan, which is the main object of this article. Here is a very brief narrative of its discovery.

Julius Schmidt, director of the observatory at Athens, recently wrote to M. Le Verrier the following letter:

"On November 11th, at $5^h\ 40^m$ in the evening, I saw a star of the third magnitude in the zenith, near ρ Cygni. Observations with the refractor of the observatory, at $9^h\ 30^m$, gave the position of the star as follows:

1876. 0	Right ascension	$21^h\ 36^m\ 50.4^s$
	North declination	$42°\ 16'\ 30.5''$

"The position for the year 1855 would be:

Right ascension	$21^h\ 36^m\ 1.2^s$
Declination	$42°\ 11'\ 1''$

"It does not occur in the Bonn "Durchmusterung des Himmels." The star is strongly yellow in color. At midnight it was more intense than μ Pegasi (which is set down as of the third magnitude in Heis's catalogue). On November 20th the star was not visible. On the 21st, 22d, and 23d, the sky at Athens was overcast. From November 24th out, it has steadily declined in brightness, and on December 8th the star was a little below the sixth magnitude."

At Paris, too, the sky was almost constantly overcast for some days after the reception of Schmidt's letter. By taking advantage of infrequent and imperfect seasons of clear sky, Prosper Henry succeeded in observing the new star. Compared with the star 915 of Weisse's catalogue (hour 21), it had this approximate position:

1876. 0	Right ascension	$21^h\ 36^m\ 50^s$
	Declination	$+\ 42°\ 16'\ 34''$

It was of the fifth magnitude, and appeared to be of a greenish color, almost blue, as compared with a neighboring star (42,304 of Lalande).

The new star was also observed at Vienna by Littrow. To him

on December 1st, as to Schmidt on November 24th, it appeared to be of from the third to the fourth magnitude; on December 3d it had fallen to the fourth magnitude, and on December 4th to the fifth magnitude. The right ascension was $24^h\ 36^m\ 50.4^s$; declination, $+42°\ 16'\ 37.7''$ for 1886. O.

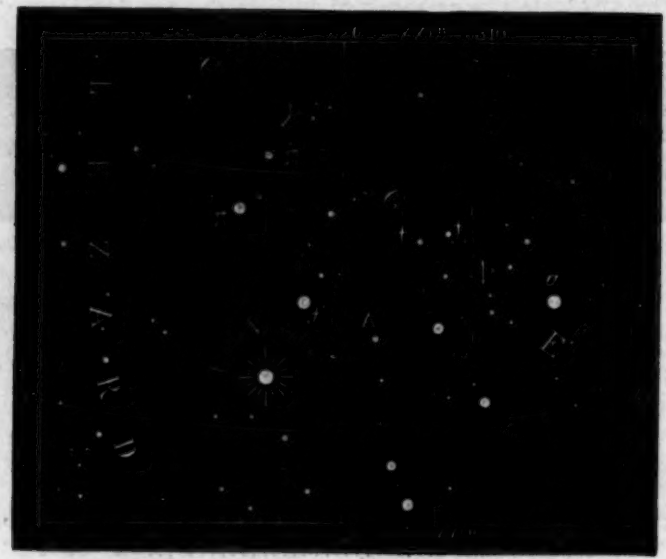


FIG. 3.—MAP SHOWING PORTION OF NEW STAR IN THE SWAN. LÉZARD—THE LIZARD; CYGNE—THE SWAN; ÉTOILE NOUVELLE—THE NEW STAR.

We may observe here that there is nothing in common between this new star and those which made their appearance in 1600 in the neck of the Swan, and in 1670 near β of the same constellation. The only point of agreement between them is their nearness to the Milky-Way.

In comparing Schmidt's observations with those of Prosper Henry, we note two important facts: the first is, the diminution of lustre, varying in eight days from the third to the fifth magnitude; and, second, the notable change of color, from a pronounced yellow to greenish blue—a change so patent that it cannot be referred to individual differences of judgment, or to atmospheric influences.

The new star of the Swan has been made the subject of a very interesting spectroscopical study. As early as December 2d, Cornu applied a spectroscope to the great equatorial in the eastern tower of the Paris Observatory. Cazin, too, employed for the same purpose the nine-inch equatorial telescope (the object-glass of which is by Léon Foucault). Both of these observers arrived at the same conclusion. The spectrum of the star, observed during a brief interval of clear sky, appeared to "consist in great part of bright lines, and hence

probably to be the result of an incandescent vapor or gas." Here, it will be seen, is a first point of resemblance to the variable star of Corona Borealis.

A second study, made by Cornu on December 4th, enabled him to define the bright lines of the spectrum. Three of them are the lines *C*, *F*, and 434 of hydrogen; a fourth line seemed to correspond to the line *D* of sodium; another to the characteristic line *b* of magnesium. Finally, two lines with the wave-lengths 531 and 451 seem to coincide, the one with the famous line 1,474 (Kirchhoff's scale) observed in the solar corona during eclipse, the other with a line of the chromosphere. These results possess so high an interest that we will here transcribe a portion of the text of M. Cornu's note:

"The spectrum of this star," he writes, "consists of a certain number of detached bright lines on a sort of luminous ground, almost entirely interrupted between the green and the indigo, so that the spectrum appears as though made up of a number of separate parts. In order to study it qualitatively, I adopted a spectroscopic eye-piece of special construction, which utilizes most of the light, and allows the observer to vary its concentration. In measuring I used a direct-vision Duboscq spectroscope. I observed only bright lines; the dark lines, if any there are, must be very minute, and escaped my observation, owing to the faintness of the star's light."

In this respect the spectrum of the star in the Swan differs from that of the star *T* of Corona Borealis, as may be seen from the figure here copied from Huggins.

We omit the details of the measurements of the positions of the lines, and pass to the results, which are stated in the following table. The bright lines, ranged in the order of their brightness, α, δ, γ, β, ζ, η, θ, ε, are eight in number, and their wave-lengths are here given in millionths of a millimetre:

	α	δ	γ	β	ζ	η	θ	ε
Lines observed.....	661	588	531	517	500	483	451	435
Hydrogen	665 (*C*)	....	..	....	..	486 (*F*)	..	434
Sodium	....	589 (*D*)	..	....	..	....	..	..
Magnesium....	....	....	..	517 (*b Mg.*)	..	....	..	..
Corona line..... ...	....	....	532	....	..	....	..	..
Chromosphere line....	....	587	..	....	..	....	447	..

From this table it is seen that there is almost perfect coincidence as regards the lines α, η, and ε, with three hydrogen-lines; as regards β, with the line *b* of magnesium; as regards δ, with the line of sodium, or, perhaps, as Cornu suggests, with the bright line *D*, of the chromosphere. The γ corresponds with a bright line also belonging to the chromosphere and the solar corona; and, finally, θ corresponds with a line of the chromosphere. The line ζ alone stands unidentified with any known line.

"If this interpretation were correct, the bright lines of the spectrum of the star would comprise exclusively the brightest and most frequent lines of the chromosphere."

In the extreme violet there is a line, the fourth of hydrogen, also noted by Dr. Young, as one of the most frequent in the spectrum of the chromosphere, the wave-length of which is 410. Cornu thinks he has often perceived this line in the spectrum of the star, but he has not been able to measure it. The distinguished observer closes his account of these interesting researches as follows:

"To sum up, the light of the star seems to have precisely the same composition as the light of the sun's envelope, the *chromosphere*. Though the temptation is strong to draw from this fact conclusions as to the physical condition of this new star, its temperature, the chemical reactions it must exhibit, I will make no comments, nor offer any hypotheses. We lack, I think, the data necessary for reaching a profitable conclusion, or at least a conclusion that can be verified. However attractive such hypotheses may be, we must not forget that they lie outside of the domain of science, and that, instead of being of service to science, they are likely to hinder its progress."

The readers of *La Nature* will permit us to add a few reflections of our own to those offered by our learned fellow-countryman. His reserve we acknowledge to be very wise, but he has expressed himself a little too strongly. Who, after perusing M. Cornu's analysis and the conclusions he has drawn, would not make the short step that here intervenes between fact and hypothesis, and assert the similarity, if not the identity, of the light of the star with that of the chromosphere? True, we cannot with certainty affirm that the apparently continuous faint spectrum in which are seen the bright lines was also its spectrum before it became visible to us, but that such is the case is highly probable. We cannot say what was the cause of this sudden development of gases, whose existence and incandescence are revealed by the star's spectrum, just as we are as yet unable to assign the cause of the sun's hydrogen protuberances. But is it nothing to class together phenomena, the only difference between which seems to be one of degree alone? The hypotheses of Huggins and Miller, as to the causes of the apparition of the star in the Corona Borealis, can of course never be verified; but no more can we verify the current hypotheses held by astronomers and physicists with regard to the presence of various chemical elements in the sun; we have here only probabilities. Such hypotheses, far from being of injury to science, are indispensable for its progress: they stimulate the observer's mind, constantly suggest to him fresh observations, and become a hinderance only when they are held to be demonstrated truths, and when men refuse to give them up after they have been proved to be erroneous, or after they have served their purpose.—*La Nature*

ANTIQUE MARBLES.

By JOHN D. CHAMPLIN, Jr.

NOTHING more forcibly attests the imperial power and magnificence of Rome, at the height of her glory, than the fragments of precious marbles which almost every excavation among her ruins brings to light. Even if her history were lost to us, these varied bits of stone would tell in language stronger than words the story of her universal dominion, when her ships sought every clime, and every land paid tribute to her luxury. This piece reflects the glowing suns of Numidia, that the green of Tempe's Vale; this was quarried on Pentelicus, this in storied Chios, and these tell of Gallic and of Hispanic conquest. Many have a double history, having served to decorate some forum or temple of the East before its spoliation by a Mummius or a Sulla.

Toward the end of the second century B. C. the Romans, who had become conversant with Greek art through their conquests, began to appreciate sculptures and precious marbles, and from that time onward almost every captured city was rifled of its treasures. Not only were all the quarries of the world put under contribution, but statues, columns, and capitals, slabs, pavements, and sometimes entire edifices, were transported to Rome. Carthage, from the time of its destruction, furnished an almost inexhaustible supply. Edrisi, the Arab geographer of the twelfth century, says that marbles of so many different species were found among its ruins that it would be impossible to describe them. Blocks thirty feet high and sixty-three inches in diameter, and columns thirty feet in circumference, were taken out.

A large fleet of vessels was employed solely in transporting marbles, and slaves or freedmen were stationed in the various ports from which they were sent, who were charged with the duty of keeping account of the number, quality, and date of shipment of all stones. In 1868 excavations on the banks of the Tiber brought to light the ancient *marmorata*, or marble-wharf, where these vessels landed their cargoes. Many blocks of precious colored marbles were exhumed here, some of colossal proportions. One of yellow African marble was twenty-seven feet long by five and a half feet wide, and weighed thirty-four tons. Another, sent from a then newly-opened quarry in the mountains north of the Adriatic, to the Emperor Nero, was marked with the name of his freedman Carynthus.

So immense was the store of marbles amassed in Rome that for centuries after her spoliation by the northern barbarians her ruined edifices were regarded as the richest of quarries, from which pope, nobles, and peasants, drew at will. Most of the mediæval churches and other public edifices now extant are decorated with the spoils of

imperial palaces, basilicas, baths, and the temples of the gods. Vast quantities of marble were even burned for lime; and, as if in retribution, Rome was robbed to beautify other cities. Her sculptured marbles were transported to Aix-la-Chapelle to decorate the buildings of Charlemagne, and the ancient capital of the world, Petrarch laments, was forced to adorn from her own bowels the slothful luxury of Naples.

Of the white marbles of antiquity the most important were the Parian and the Pentelic, both the product of Greek quarries. The Parian was obtained from Mount Marpessa, in the island of Paros, one of the Cyclades, whence it was sometimes called Marpessian. It was also called *lychnites*, because, says Pliny, the quarries were worked by lamplight. Dodwell disputes this, averring that the quarries are cut down the mountain-side and open to the light; and he suggests that the marble was so called from its glittering fracture, or its translucence. This leads one to doubt whether Dodwell ever visited them, for Bory Saint-Vincent, of the French commission to the Morea, expressly describes them as subterranean, and says the entrance of the principal one was so filled up at the time of his visit that he was obliged to creep to enter it. There are three quarries on the mountain, and the largest has several lateral cuttings. The marks of the ancient wedges are everywhere visible, and it is evident from the manner in which the blocks were taken out that the utmost care was exercised to avoid waste. In consequence of the numerous fissures through the beds, comparatively small blocks could be obtained, generally not more than five feet in length.

Parian marble is of a yellowish white, very near the tint of white wax. Theocritus compares it to the color of teeth. It was, therefore, considered better adapted for the representation of human flesh than any other material. Its grain is much coarser than that of the Pentelic marble, but it takes a most exquisite polish, and, as it gradually hardens by exposure to atmospheric air, it resists decomposition for ages. To this quality is attributable the fine state of preservation of many of the most celebrated of the antique statues, such as the "Venus de' Medici," the "Diana Venatrix," the "Juno Capitolina," the "Ariadne," and the colossal "Minerva"—otherwise called the "Pallas of Velletri"—all of which are of Parian marble.

The neighboring island of Naxos produced a white marble scarcely inferior to that of Paros, but exhibiting a little more advanced state of crystallization. The marble, too, of Tenos, an island north of Paros, and of Thasos, the most northerly of the Ægean group, was considered nearly equal to that of Paros. Chios, Lesbos, Samos, and several other islands of the archipelago, also produced white marbles, generally of a more snowy white than the Parian. They are called usually by the Italians *marmo Greco*.

In the palmy days of Greek art the Athenians gave the preference

to the Pentelic marble, rather than to that of Paros, probably because it was more accessible to Athens, the quarries being on Mount Pentelicus, only about eight miles from the city. It is finer in grain than the Parian, and is whiter, but it is less translucid, and it has a tendency to exfoliate under atmospheric influence, so that it loses in time its polished surface. It is marked, too, by occasional zones of greenish talc, whence it is called by the Italian sculptors *cipolino statuario*, from its resemblance to an onion (*cipola*). It is sometimes called also *marmo salino*, from its salt-like grains. The Parthenon, the Propylæa, the Erechtheum, and most of the other principal buildings of Athens, were constructed of Pentelic marble, and it was also the material of some of the most celebrated of the ancient statues, such as the "Venus" of the Capitol, the "Pallas" of the Albani villa, the "Indian Bacchus," and many portrait busts.

The Pentelic quarries, says Dodwell, are cut in perpendicular precipices in the side of the mountain. The marks of the tools are everywhere visible, and the tracks of the sledges on which the immense masses were drawn down the declivity to the plain are still to be seen. Several frusta of columns and other blocks lie at the base of the excavation, just as they were left by the ancient quarrymen. One of the larger excavations is worked now.

The Hymettan marble, from Mount Hymettus on the southeast side of Athens, was employed in Xenophon's time in the construction of temples, altars, shrines, and statues, throughout Greece, but especially in Athens. The Romans used it to a much greater extent than the Pentelic, partly because the quarries were nearer the sea, and partly because its peculiar tint became the fashion. It was of a much less brilliant white than the Pentelic, in some places becoming almost gray. It was used chiefly for buildings. According to Pliny, Lucius Scaurus was the first in Rome to decorate his house with Hymettan columns, 104 B. C. The statue of Meleager, in Paris, is made of this marble.

In the time of Julius Cæsar quarries of white marble were opened at Luna, on the coast of Etruria, and thenceforth Rome drew her supply of building-marbles from this place, almost to the exclusion of the Greek marbles. The Pantheon, and many other public buildings, were constructed of it. It was soon found to be adapted also for statuary, and finally came to be preferred to the Parian. The "Antinous" of the Capitol, now in the Paris Museum, is of this marble, and, according to some, the "Apollo Belvedere" also; but the Roman sculptors think the latter is a Greek marble. The marble of Luna, called by the ancients *marmor Lunense*, and which is the same as the modern Carrara, is whiter than either the Parian or Pentelic, and some of its veins are not inferior in beauty of grain and in softness to the former.

In 1847 a quarry of white marble was opened at Maremma, about

thirty-five miles from Leghorn, which bore many evidences of having been worked in ancient times. It closely resembles the Parian in color and grain, works smoothly, and takes a high polish.

White marbles were also obtained by the ancients from Mount Phelleus, Rhamnus, and Sunium, in Attica; Demetrias, in Thessaly; on the river Sangarius, in Phrygia; from near Alexandria Troas; from Mount Prion, near Ephesus; from Cappadocia, and from Mount Libanus, the modern Lebanon.

The marbles of Phelleus, Rhamnus, and Sunium, were of good color, but were coarse, and less homogeneous than the Pentelic. The Sangarian marble was sometimes called Coralitic. The Cappadocian was called Phengites (Φέγγος), on account of its translucence. The temple of Fortuna Seia, built by Nero within the precincts of his Golden House, was built of this stone; and, although it had no windows, it is said to have been perfectly light when the door was closed. The marble of Mount Libanus, usually called Tyrian, was probably the material of Solomon's Temple and of Herod's palace. The *Scala Santa* in the Lateran Palace, Rome, said to have been brought from Pilate's house in Jerusalem, is of this marble, which is a clear blue-white.

The Proconnesian marble, a pure white with black veins, was quarried in the island of Proconnesus, in the Propontis. The celebrity of this stone has changed the name of the island to Marmora, and also given its modern name (Sea of Marmora) to the Propontis. This marble was also called Cyzican, because it was largely used in the city of Cyzicus, opposite the island in Mysia. The palace of Mausolus, at Halicarnassus, was built of it. It was also much used at Constantinople, under Honorius and the younger Theodosius. Several columns of it in the mosque of St. Sophia were spoils of the temple of Cybele at Cyzicus.

A white marble, with yellow spots, was brought from Cappadocia, and a similar marble from Rhodes, but the spots were of a brighter, more golden, yellow. White marble, with black spots, was quarried in the Troad.

But the most beautiful of the antique variegated marbles, with a white base, was the Synnadic, Docimæan, or Docimite, sometimes called *marmor Phrygium*. It was quarried at the village of Docimia, not far from Synnada, in Phrygia Major. The ancient authorities generally describe it as pure white, marked with red or purple veins, which the poets compared to the blood of Atys, slain at Synnada; but Hamilton, who visited the quarries about 1835, says that they yield several different kinds. He mentions white, bluish-white, white with yellow veins, white with blue veins, and white with blue spots, the latter having almost a brecciated appearance. He describes the principal quarry as worked horizontally into the hill, the sides of which are cut away perpendicularly to a great height to secure the splendid columns for which it was famous. Strabo says that pillars

and slabs of surprising magnitude and beauty, approaching the alabastrite marble in variety of colors, were conveyed thence to Rome, notwithstanding the long land-carriage of more than 100 miles to the place of shipment. The quarries are entirely surrounded by trachytic hills, to which, says Hamilton, the marble "owes its crystalline and altered character, being to all appearance a portion of the older secondary limestone caught up and developed by the protruded volcanic rocks, and crystallized by igneous action."

The alabastrites marble of the ancients, or onychites, was not a marble proper, but a hard carbonate of lime, identical in composition with stalagmite, the modern alabaster. It was quarried, says Pliny, near Thebes, in Egypt, and Damascus. When first brought to Rome it was considered almost a precious stone, and was made into cups and small ornaments, such as the feet of couches and chairs. When Balbus decorated his theatre, in the time of Augustus, with four small columns of this stone, it was noted as an unprecedented occurrence; but, in the reign of Claudius, Callistus, a freedman of that emperor, adorned his banquet hall with thirty large columns of alabastrites. The ancient quarries were reopened by Mehemet Ali, Viceroy of Egypt, to obtain material to build his mausoleum at Cairo. The four magnificent pillars of this marble that support the baldacchino over the altar in the church of San Paolo fuori le Mura, in Rome, were presented by him. Each is a monolith forty feet long.

Of the yellow marbles of antiquity, that called by the Italians *giallo antico* is the rarest and most beautiful. There are several varieties of it, varying in tint from a cream-yellow to the deepest chrome-yellow, sometimes shading into red and purple hues. Some is as bright as gold (*giallo dorato*), some of an orange-shade (*giallo capo*), and some, extremely rare, of a canary-color (*giallo paglia*). The ancient writers compared it to saffron, to sunlight, and to ivory grown yellow with age. Some of it is variegated with black or dark-yellow rings. The grain is exceedingly fine. Its colors are derived entirely from carbonaceous matter. Among the finest existing specimens of this marble are the large columns in the Pantheon at Rome, and a single pair in the Arch of Constantine. The *giallo antico* was called *marmor Numidicum* by the Romans, but the precise site of the quarries is not yet ascertained. M. Fournel believes that the yellow marble of Philippeville, Algeria, which closely resembles it in varying tints, is identical with it. The island of Melos and Corinth also produced yellow marbles, and in the time of Justinian a marble of a fiery yellow was quarried in the neighborhood of Jerusalem.

Among the most celebrated marbles of the ancient world was the *rosso antico*, or red antique. Its color passes from a red, almost scarlet, to a wine-lees or blood-red, which is divided by parallel layers of white, and sometimes also intersected by a network of delicate black veins. Its variation in tint is probably according to the quan-

tity of the oxide of iron contained in it. Until lately this marble was known only through its remains, and it has generally been ascribed to Egypt. The largest ancient specimens preserved are the fourteen slabs composing the double flight of steps in the church of San Prassede, Rome. Napoleon I. at one time intended to carry these to Paris to ornament his throne. There are several statues of *rosso antico*, including the "Antinous" in Paris and the "Marcus Agrippa" in the Grimani Palace, Venice, and many medallion portraits. It is now ascertained that this beautiful marble was not Egyptian, but Greek. It was quarried on the coast of the gulf of Laconia, near what is now the bay of Scutari. The quarry lies near the sea, and large blocks cut by the ancients are still to be seen there. In 1851 the Greek Government sent specimens from it to the London Exposition, and it was fully recognized as the famous *rosso antico*.

There are many varieties of the marble called red and white antique, but they are so near alike that it is impossible to distinguish them by description alone. They are variously called by the Italians *rosso annulato*, *serpentelo*, *vendurino*, *fiorito*, *cotonello*, etc. They are found only in the Roman ruins, and their quarries are unknown. The marble called *cervelas* is of a deep red, with numerous gray and white veins. It is supposed to have been brought from Africa.

The ancients were acquainted with many kinds of green marble, one of the most noted of which was the *marmor Atracium*, called by Julius Pollux Thessalian, and identical with the *verde antico* of the Italians. The quarries were on Mount Ossa, near the entrance of the vale of Tempe, and not far from Atrax in Thessaly, whence it derived its name. It is a species of breccia, whose paste is a mixture of talc and limestone, interspersed with fragments of white marble. But the verde antique marbles differ from the modern breccias in that the colors are so blended that the line of demarkation is not perceptible. The Erechtheum in Athens was adorned with columns of verde antique, and it was one of the marbles selected by Justinian for the decoration of St. Sophia. The eight splendid columns of it still to be seen in the mosque are said to have been taken from the temple of Diana at Ephesus.

The celebrated Carystian marble, the *cipolino verde* of the Italians, derived its name from Carystus, a town at the foot of Mount Ochе, in the island of Eubœa, where it was quarried. The temple of Apollo Marmarinus of Carystus was named from this quarry. It is a true steatitic limestone or cipolin, and is of a beautiful grayish green, with white zones and spots, and sometimes sprinkled with different colors. It was easily obtained in very large blocks, suitable for columns, and was largely used in the temples and other public buildings in Athens and Rome. An English traveler, who visited the quarry lately, found seven entire columns on the site, about three miles from the sea, just as they were left by the ancient workmen.

The *marmor Lacedæmonium*, *Laconicum*, or *Spartum*, of the Romans has always been regarded as a species of verde-antique marble. Clarke says that it differed from the Atracian only in being variegated with black or dark-green serpentine instead of with white. But M. Boblaye, the mineralogist of the French commission to the Morea, has proved pretty conclusively that it was not a marble but a true porphyry, and probably identical with the *ophites* of the ancients, which Pliny says was so called from its resemblance to the skin of a serpent (ὄφις). Pausanias calls it Crocean stone (Κρόκεων λίθος). The French discovered the quarries near the ancient Croceæ, on the road from Sparta to Gythium, and about two miles from the modern village of Levétzova, in Laconia. The stone is of a dark grass-green, strewed with little parallelograms of a lighter green, sometimes approaching white and sometimes yellow. Procopius compares its color to emerald, and Statius and Sidonius call it a grass-green. Eurycles, the Spartan architect, used this stone in decorating the baths of Neptune at Corinth; and it was quarried to a large extent by the Romans, who enriched the monuments of Greece, Italy, and Gaul, with it.

The Augustan and Tiberian marbles, so fashionable in Rome under those emperors, were obtained in Egypt. They are breccias composed of fragments of greenstone, gneiss, and porphyry, cemented with a calcareous paste. They are similar in color, a bright green, spotted and streaked with dark green, reddish gray, and white; the only difference being, according to Pliny, that in the Augustan the figures undulate and curl to a point, while in the Tiberian the streaks are not involved, but lie wide asunder. It is probable that these marbles were quarried in the mountains between Thebes and the Red Sea. Inscriptions in the ancient quarries there, near the well of Hammamat, show that they were worked in the sixth dynasty of Manetho. A green marble called Memphites was quarried near Memphis in Egypt.

There were many other varieties of green marble known to the ancients, such as the red-spotted green antique, having a dark-green ground marked with small red and black spots and white fragments of *entrochi;* the *marmo verde paglioco*, yellowish green; and leek marble, of the color of a leek; but they exist only in small fragments, and their quarries are unknown. Another variety of green marble was found in the island of Tenos.

A blue marble is said to have been obtained in Libya. The island of Naxos yields a dark blue elegantly striped with white, Tenos a light blue veined with dark blue, and Scyros many kinds of blue and violet breccias, with other colors variously disposed. Scyros was one of the chief places whence the ancients derived their variegated marbles, and its quarries furnished many varieties closely resembling the famous marbles of other localities. Strabo says it pro-

duced the Carystian, Deucalian, Synnadic, and Hierapolitic marbles. The quarries of Tenos are still worked to some extent, but those of Scyros and Naxos remain almost as the ancients left them.

Of the black marbles of antiquity that now called *nero antico*, or black antique, was the most celebrated. It is more intensely black than any marble now quarried, the black marbles of France appearing almost gray beside it. It occurs only in sculptured pieces, and its origin is unknown; but Faujas discovered a quarry which had been worked by the ancients, about two leagues from Spa, not far from Aix-la-Chapelle, the marble of which closely resembles the ancient specimens. The largest masses known of *nero antico* are two columns in the church of Regina Cœli at Rome, but there are also some fine specimens in the Museum of the Capitol and in other collections. Some suppose it to be identical with the *marmor Lucullum*, which was introduced at Rome by Lucullus in the first century B. C., according to Pliny from Melos (another reading is Chios), but according to other authorities from Egypt or Libya, whence it is sometimes called *marmor Libycum*. Pliny says that Marcus Scaurus had pillars of it thirty-eight feet high in the atrium of his house. The Chian marble, a deep, transparent black, sometimes variegated with other colors, was quarried on Mount Pelinæus, in the island of Chios. A fine black marble was quarried on Mount Tænarus, in Laconia, and in the island of Lesbos, and a blue-black marble in Lydia. One of the most beautiful of the antique breccias, the African breccia, has a deep-black ground, variegated with fragments of grayish white and deep red or purplish wine-color. The grand antique breccia consists of large fragments of black marble united by veins of shining white. Columns of this and of African breccia are in the Paris Museum, but their quarries are unknown.

ON THE WONDERFUL DIVISIBILITY OF GOLD AND OTHER METALS.

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IT is both curious and interesting to notice how frequently original investigators, working from different standpoints, and with entirely dissimilar objects in view, will, independently of each other, accumulate a mass of observations corroborative of some one physical law, but which require to be collated in order to reveal their mutual relations.

The motive of this paper is to collect together several observations illustrating the divisibility of gold (made either as the direct

object of experiment, or as incidental to other investigations), and to present them in a condensed form to the readers of THE POPULAR SCIENCE MONTHLY.

Some of these experiments (notably those of Faraday) present the curious anomaly of revealing to the physical sense of sight particles of matter which are almost too infinitesimal for the mind's eye to conceive, thus seeming to reverse the order of scientific investigation which usually prolongs the mental vision far beyond the region of possible physical revelation.

The experiments to be described have been arranged in the following order:

1. On the natural dissemination of gold.
2. Beating into thin leaves.
3. Faraday's researches.
4. Depositing by the galvanic battery.
5. Vaporization by the electric spark.

Some years since a very interesting series of experiments was made by the late Mr. J. R. Eckfeldt, then chief-assayer of the mint at Philadelphia, and his associate, Mr. W. E. DuBois (the present incumbent), upon the "Natural Dissemination of Gold." The results were presented to the American Philosophical Society, in the form of a paper, by Mr. DuBois, and published in their "Proceedings" of June 21, 1861.

The precious metal was found disseminated in marvelously fine division through a number of substances where its existence had not been previously suspected.

In the clay of which the Philadelphia bricks are made, gold was found in the proportion of about forty cents' worth to the ton. Each brick contains a sufficient amount of gold to make a glittering show of two square inches, if brought to the surface in the form of leaf.

An estimate of the thickness of the bed of clay under the city revealed the startling fact that more gold lies securely locked up in it than has been procured, according to the statistics, from Australia and California. A specimen of galena from Buck's County, Pennsylvania, yielded gold in the proportion of one part of gold in six million two hundred and twenty thousand (6,220,000) parts of ore; not quite ten cents to the ton. The report of these experiments concludes as follows: "Of this we may be confident, that the atoms of gold are homogeneously and equably dispersed through the clay, or other matrix; but by what natural process or for what final cause these fine particles should be thus diffused, seems quite beyond the reach of human philosophy."

The remarkable malleability of fine gold was a property well known to the ancients. Homer refers to the art of gold-beating, and Pliny mentions that an ounce of gold was beaten into seven

hundred and fifty leaves, "each leaf being four fingers square," or about three times thicker than our ordinary gold-leaf. On the coffins of the Theban mummies, gold-foil has been discovered of extraordinary thinness. The ancient Peruvians covered the walls of their temples with very thin sheets of gold, and the rude specimens of gilding on the palace of Tippo Saib, at Bungalore, prove that the art of gold-beating was practised in India. We also have Biblical authority for the antiquity of the art.[1]

Experiments made in modern times have shown that a single grain of gold may be beaten out so as to cover a space of seventy-five square inches; the thickness of the leaf is then only the three hundred and sixty-seven thousand six hundred and fiftieth ($\frac{1}{367,650}$) part of an inch, or about twelve hundred times thinner than an ordinary sheet of printing-paper.

Faraday states in his researches on "The Experimental Relations of Gold (and other Metals) to Light"[2] that a leaf of beaten gold occupies an average thickness of no more than $\frac{1}{4}$ to $\frac{1}{8}$ part of a single wave of light. He reduced the thickness of gold-leaves at pleasure, by spreading them upon glass plates and gradually dissolving the metal by means of a weak solution of cyanide of potassium. "By this means," he says, "I think fifty or even one hundred might be included in a single progressive undulation of light."[3]

Faraday's researches upon the nature of thin films of gold and other metals, and upon the size of finely-divided particles of gold diffused through various liquids, are of a most interesting and refined character. Availing himself of the well-known reducing power of phosphorus, he floated small particles of it upon the surface of weak solutions of chloride of gold. In the course of twenty-four hours he found that the surfaces of the liquids were covered with films of metallic gold, which were thicker near the pieces of phosphorus "possessing the full golden reflective power of the metal," but becoming so thin by gradations as to be scarcely perceptible. "They acted as thin plates upon light, producing the concentric rings of colors round the phosphorus at their first formation, though their thickness then could scarcely be the $\frac{1}{100}$, perhaps not the $\frac{1}{100}$, of a wave-undulation of light."

By treating very dilute solutions of gold with phosphorus he obtained the metal diffused through the liquid in extremely fine particles, producing a beautiful ruby-color. These particles, "when in their finest state, often remain unchanged for months, and have all the appearance of solutions, but they never are such, containing, in fact, no dissolved but only diffused gold. The particles are easily rendered evident by gathering the rays of the sun (or a lamp) into a cone by a lens,

[1] "And they did beat the gold into thin plates" (Exodus xxxix. 3).

[2] "Philosophical Transactions," 1857.

[3] Faraday's "Researches in Chemistry and Physics."

and sending the part of the cone near the focus into the fluid; the cone becomes visible, and though the illuminated particles cannot be distinguished, because of their minuteness, yet the light they reflect is golden in character and seen to be abundant in proportion to the quantity of gold present. Portions of gold so dilute as to show no trace of gold by color or appearance can have the presence of the diffused solid particles rendered evident by the sun in this way. . . . The state of division of these particles must be extreme; they have not as yet been seen by any power of the microscope."

Faraday further tells us that he endeavored to obtain an idea of the quantity of gold in a given ruby fluid, and for this purpose selected a plate of gold ruby glass, of good full color, to serve as a standard, and he compared the different fluids with it, varying their depth until the light from white paper, transmitted through them, was apparently equal to that transmitted by the standard glass. Then, known quantities of these ruby fluids were evaporated to dryness, the gold converted into chloride, and compared, by reduction on glass and otherwise, with solutions of gold of known strength. "From these considerations it would appear that one volume of gold is present in the ruby fluid in about 750,600 volumes of water; and that, whatever the state of division to which the gold may be reduced, still the proportion of the solid particles to the amount of space through which they are dispersed must be of this extreme proportion. This accords perfectly with their invisibility in the microscope; with the manner of their separation from the dissolved state; with the length of time during which they can remain diffused; and with their appearance when illuminated by the cone of the sun's rays."

While all the statements of this profound investigator were so carefully kept within the limit of actual observation, he tells us, in conclusion, that he not only believed the gold to be diffused in solid metallic particles, but that he also believed "there may be particles so fine as to reflect very little light indeed, that function being almost gone."

The art of gold-plating has become so extensive in its application to a great variety of ornamental objects, that it seemed to the writer an interesting question "How thick a film is required to produce a fine gold-color?" He was unable to find, on inquiry, that any careful notes to determine this point have been recorded,[1] and he recently made some experiments with the following results: A sheet of copper was rolled down to an average thickness of $\frac{5}{1000}$ of an inch. Two plates were cut from this strip, 4 by 2½ inches, having a metallic surface of twenty square inches each. These plates were boiled in alkali, to remove grease, polished, and accurately weighed on a bal-

[1] It is stated that when a cylindrical bar of silver is coated with gold and drawn into the fine wire used in embroidered housings, etc., a grain of gold will cover 345.6 feet of wire.

ance sensitive to the twentieth of a milligramme, or the $\frac{1}{1300}$ of a grain.

No. 1 weighed $126\frac{444}{1000}$ grains troy.
" 2 " $132\frac{55}{100}$ " "

A gold "blush" of sufficient thickness to produce a fine gold-color was then deposited by the battery. The plates were washed in distilled water, dried, and reweighed without rubbing, and were found to have each gained in weight exactly one-tenth ($\frac{1}{10}$) of a grain. It thus appears that one grain of gold may be distributed, by the galvanic deposit, over the surface of two hundred square inches, as contrasted with seventy-five square inches by beating. In other words, the metal is more than two and a half times thinner in the former case than in the latter, or $\frac{1}{880000}$ part of an inch, as compared with $\frac{1}{2}\frac{1}{2000}$ of an inch.

A still thinner deposit of gold could, of course, be detected on the delicate assay-balance, but, owing to the transparency of the film, it would not possess the true gold-color. It seemed important to ascertain whether the gold was evenly distributed over the copper surface, or whether it was deposited in spots. The strips were accordingly examined under a microscope.

A careful examination showed that there were no exposed surfaces of copper, and the gold appeared to have a fine, bright, smooth surface. This, however, was not considered sufficient proof, and several expedients were tried to obtain the gold films free from the copper plate, in order that they might be examined by transmitted light. Owing to their extreme thinness this was difficult to accomplish. One method, which was partially successful, was to heat the copper plates to a cherry red in the annealing muffle of an assay-furnace. On cooling, the gold film peeled off in flakes with a thin backing of oxide of copper; these flakes were pressed between two plates of glass, and nitric acid allowed to flow in by capillary action. The acid dissolved the copper; leaving a film of free gold. The difficulty was, that the bubbles of gas formed perforated the film of gold. Another plan was then tried. The gold-plating was removed from one surface of the copper plates by means of fine emory-paper. Pieces about one inch square were immersed for several days in very weak nitric acid. The copper was entirely dissolved, and detached films of gold were found floating intact on the surface of the liquid; these were carefully collected on strips of glass, washed with distilled water, and dried; they then firmly adhered to the glass.

When examined by *reflected* light they retain their brilliant gold color and lustre, but when viewed by *transmitted* light they are bright green and very transparent; the color is an even shade, having none of the mottled appearance of gold-leaf when seen by transmitted light, caused by its very uneven thickness. This monotone appears to be a positive indication of uniform thickness, for, when two

films were superposed, one upon the other, the color was very perceptibly darkened; even when subjected to a magnifying power of 1,000 diameters the films retain their continuous character, though the brilliance of the green color is of course diffused. The dimensions of the waves of light, when decomposed by the prism, have been carefully measured. There are 47,000 green waves in the space of an inch; dividing the estimated thickness of our gold film by this number, we find that the thickness of the film is less than $\frac{1}{10}$ part of a single undulation of green light.

In the course of an examination made by the writer upon "The Practicability of assaying Metals used in Coinage, by means of Spectrum Analysis, made in and for the Assay Department of the United States Mint at Philadelphia,"[1] it was noticed that a large number of very powerful electric flashes might be passed between two slips of metal without any apparent loss, and an important query suggested itself, viz., whether the amount of metal vaporized by each spark was not too infinitesimal to be determined. In order to ascertain this point the following experiments were tried: Having weighed small electrodes averaging 18 milligrammes each with the greatest possible accuracy upon the gold assay-balance of the mint, which is sensitive to $\frac{1}{10}$ of a milligramme, or $\frac{1}{1000}$ of a grain troy, and having arranged a spark-register, it was found that 1,000 sparks might be passed between these poles, each spark showing the spectrum of the metal distinctly, and yet the loss in weight was too small to be made the base of calculation. Thus a gold pole lost in weight, after passing 1,000 sparks, $\frac{1}{10000}$ of a grain; this gives for each spark $\frac{1}{10000000}$ of a grain of gold, producing a bright spectrum.

The number was then increased to 3,000 sparks as the test. The loss of weight depends, of course, upon the electric volume, and in the experiments tabulated an endeavor was made to keep the latter constant. The tables (marked A and B) show that the loss in weight is marvelously small, averaging less than $\frac{1}{10}$ of a milligramme of gold for 3,000 sparks. To give the amount for each spark, this must be divided by the number of sparks; thus, in round numbers, an electrode loses $\frac{3}{10000}$ of a grain after passing 3,000 sparks; or, for 1,000 sparks, $\frac{1}{10000}$ of a grain; or, for each spark, $\frac{1}{10000000}$ of a grain. The experiments made by M. Cappel to determine the *minimum* amount of each element that would show a spectrum have been published in tabular form. His method was to volatilize "solutions of the metallic salts between the poles of a small induction-coil in Mitscherlich's glass tubes with platinum wicks. A series of solutions, each one-half the strength of the preceding one, was prepared from a number of metallic chlorides. The spectrum in connection with the positive pole was continually observed, while increasingly-concentrated solutions were

[1] Published in the "Proceedings of the American Philosophical Society," vol. xiv., p. 162.

brought in succession into the action of the spark until the lines of the substance were clearly visible." If a skeptical person refuse to believe the results of Cappel, who tells us that $\frac{1}{100}$ of a milligramme ($\frac{1}{3860}$ of a grain) of nickel will *just* write the signature of that metal, what will he say when, glancing at Table B, appended hereto, he finds the statement that $\frac{1}{10000}$ of a milligramme ($\frac{1}{38600}$ of a grain) will sign its name *in brilliant characters!* And yet the writer does not hesitate to say that even a *smaller* amount of this metal will show a spectrum, for in these experiments a much stronger spark was used than was necessary to show a visible spectrum. When reduced to a minimum, by means of a miniature Leyden jar, improvised out of a test-tube, which still gave a distinct spectrum, the loss in weight, after passing 3,000 sparks, was *absolutely inappreciable* on the balance. The tables show another curious and unexpected result, viz., that the loss in weight of the volatile metals very slightly exceeds, and in some cases does not equal, the loss of the less volatile metals. Thus, in three different experiments of 3,000 sparks each, copper loses but $\frac{1}{17}$ milligramme, while gold loses $\frac{5}{10}$ milligramme."[1]

In one experiment the number of sparks was increased to 10,000, and the loss in weight was nearly proportioned to the increased number. In this case the sparks were passed at the rate of about 250 per minute.

TABLES.

The first column shows weight of metallic electrodes (in milligrammes) before passing the sparks.

The second column shows weight after passing 3,000 sparks.

The third column shows total weight of metal volatilized (in fractions of a milligramme).

The fourth column shows the amount of metal volatilized by *each* spark (in fractions of a milligramme).

The fifth column shows the amount of metal volatilized by each spark (in fractions of a grain troy).

TABLE A.

	1.	2.	3.	4.	5.
Upper pole, gold	16.6	15.9	.7	$\frac{1}{4286}$	$\frac{1}{27000}$
Lower " "	16.7	16	.7	$\frac{1}{4286}$	$\frac{1}{27000}$
Upper " copper	18.5	18.4	.1	$\frac{1}{30000}$	$\frac{1}{192000}$
Lower " "	18.5	18.4	.1	$\frac{1}{30000}$	$\frac{1}{192000}$
Upper " gold and copper	24	23.4	.6	$\frac{1}{5000}$	$\frac{1}{32000}$
Lower " "	24	23.4	.6	$\frac{1}{5000}$	$\frac{1}{32000}$
Upper " tin	20	19.6	.4	$\frac{1}{7500}$	$\frac{1}{48000}$
Lower " "	20	19.4	.6	$\frac{1}{5000}$	$\frac{1}{32000}$
Upper " silver	24.8	24.6	.2	$\frac{1}{15000}$	$\frac{1}{97000}$
Lower " "	25.1	25	.1	$\frac{1}{30000}$	$\frac{1}{194000}$
Average lead	91.6	90	1.6	$\frac{1}{1875}$	$\frac{1}{12100}$

[1] "The Spectroscope in its Application to Mint-Assaying." *Journal of the Franklin Institute*, October, 1874. Reprinted in the *Quarterly Journal of Science*, January, 1875.

TABLE B.

	1.	2.	3.	4.	5.
Upper pole, gold	20.5	20	.5	$\frac{1}{200}$	$\frac{1}{392}$
Lower " copper	10	9.9	.1	$\frac{1}{400}$	$\frac{1}{784}$
Upper " gold and copper	21	20.4	.6	$\frac{1}{200}$	$\frac{1}{392}$
Lower " copper	20.2	20	.2	$\frac{1}{150}$	$\frac{1}{576}$
Upper " silver	6	5.8	.2	$\frac{1}{150}$	$\frac{1}{576}$
Lower " tin	20	19.4	.6	$\frac{1}{200}$	$\frac{1}{392}$
Upper " nickel	12	11.95	.05	$\frac{1}{600}$	$\frac{1}{1176}$
Lower " "	12	11.9	.1	$\frac{1}{300}$	$\frac{1}{784}$

While it is probable that (with the exception, perhaps, of Faraday's researches) we have not here indicated the *smallest* particles of metal which it would be possible to determine by the delicate means at our disposal, it is thought that the experiments recorded may prove interesting, as showing what has been, and what may be, accomplished in this direction; and, lest any incredulous reader should fancy that, when we speak of weighing the three million eight hundred and eighty-thousandth part of a grain of metal, we are toying with imaginary fractions, we would refer him to Sir William Thomson's estimate of the size of the final molecules;[1] compared with which this unit is as large as the famous Philadelphia cobble-stones compared with grains of sand upon the sea-shore. In conclusion, we are led to appreciate the wisdom as well as the wit of the distich—

> "E'en little fleas have lesser fleas upon their backs to bite 'em;
> And these again have lesser fleas, and so—*ad infinitum*."

MOVEMENTS OF JUPITER'S CLOUD-MASSES.

By RICHARD A. PROCTOR.

IF Jupiter be regarded as a planet resembling our earth in condition, we find ourselves compelled to believe that processes of a most remarkable character are taking place on that remote world. It is singular with what complacency the believers in the theory that all the planets are very much alike accept the most startling evidence respecting disturbances to which some among those brother worlds of ours must needs on that hypothesis have been subjected. Mighty masses of cloud, such as would suffice to enwrap the entire globe on which we live, form over large regions of Jupiter or Saturn, change rapidly in shape, and vanish, in the course of a few minutes; and many are content to believe that what has thus taken place resembles the formation, motion, and dissipation, of our own small clouds,

[1] He fixes the limit between the $\frac{1}{25000000}$ and the $\frac{1}{250000000}$ of an inch, and says that they are "pieces of matter of measurable dimensions, with shape, motion, and laws of action; intelligible subjects of scientific investigation."

though the sun pours but about a twenty-seventh part of the heat on Jupiter, and but about a hundredth part on Saturn, which we receive from his rays. The outline of Jupiter, as indicated by the apparent position of a satellite close to his disk, expands and contracts through thousands of miles, yet the theory that Jupiter is still intensely hot must not for a moment be entertained, though the expansion and contraction of the solid crust of a cool planet through so enormous a range would vaporize a portion of its mass exceeding many times the entire volume of our earth. Saturn is seen by Sir W. Herschel and Sir J. Herschel, by Sir G. Airy, Coolidge, the Bonds, and a host of other observers, to assume from time to time the square-shouldered aspect, a change which—to be discernible from our distant standpoint—would imply the expansion and contraction of whole zones of Saturn's surface through 4,000 or 5,000 miles at least; yet it is better to believe that these stupendous changes have affected the solid crust of a planet like our earth than to admit the possibility that the outline we measure is not that of the planet itself, but of layers of cloud raised to a vast height in the deep atmosphere surrounding a planet still glowing with its primeval fires.

The phenomena I am now about to consider belong to the same category. They are utterly inexplicable, or only explicable by the most sensational assumptions as to the processes taking place on Jupiter, if we adopt the old theory of Jupiter's condition; while if we regard Jupiter as an intensely-heated planet surrounded by and entirely concealed within a cloud-laden atmosphere several thousand miles in depth, they at once admit of the most simple and natural explanation.

It has, of course, long been known that the belts of Jupiter are phenomena of his atmosphere, not of his surface. The belts of lightest tint have been regarded as belts of cloud, and the darker belts as either the real surface of the planet seen between the cloud-belts, or else as lower cloud-layers, appearing darker because in shadow. Accordingly, when features of the belts have been watched in their rotational circuit, it has been clearly recognized that the rotation determined in this way is not necessarily or probably the true rotation of the planet itself. Further, it has been proved, beyond all possibility of question, that some at least among the spots upon the planet's belts have a motion of their own; for whenever two spots in different Jovian latitudes have been observed, it has been almost constantly noticed that the one nearer the equator has had a greater rotation rate than the other. Again, it has sometimes happened that instead of two spots, in different latitudes, a well-defined dark streak or opening, having its two extremities in different latitudes, has remained long enough to be observed during several rotations of the planet. In these cases it has been observed that the end of the streak nearest the equator has traveled fastest, not only absolutely, but in longitude, insomuch that the position of the streak has notably altered.

Thus, in February, 1860, Mr. Long, of Manchester, noticed across a bright belt an oblique dark streak. "Its position" (I quote from a paper of my own written six years ago, when as yet the theory now before us was in its infancy) "might be compared to that of the Red Sea on the globe of the earth, for it ran neither north and south nor east and west, but rather nearer the former than the latter direction. The length of this dark space—of this rift, that is, in the great cloud-belt—was about 10,000 miles, and its width at least 500 miles; so that its superficial extent was much greater than the whole area of Europe." It remained as a rift certainly until April 10th, or for six weeks, and probably much longer. It passed away to the dark side of Jupiter, to return again after the Jovian night to the illuminated hemisphere, during at least a hundred Jovian days; and assuredly nothing in the behavior of terrestrial clouds affords any analogue to this remarkable fact. "This great rift *grew*, lengthening out until it stretched across the whole face of the planet, and it grew in a very strange way; for its two ends remained at unchanged distances from the planet's equator, but the one nearest to the equator traveled forward (speaking with reference to the way in which the planet turns on its axis), the rift thus approaching more and more nearly to an east and west direction." The rate of this motion was perhaps the most remarkable circumstance of all. Mr. Baxendell, one of the observers of the rift, and one of our most experienced telescopists, thus describes the changes seen in the belt: "Since Mr. Long first observed the oblique streak on February 29th, it has gradually extended itself in the direction of the planet's rotation, at the average rate of 3,640 miles per day, or 151 miles per hour, the two extremities of the belt remaining constantly on the same parallels of latitude. The belt also became gradually darker and broader."[1]

Apart from the evidence afforded by this rift respecting the swift motions of the cloud-masses enwrapping Jupiter (for a velocity of 151 miles per hour exceeds that of the most tremendous hurricanes on our earth), it has always seemed to me that this one series of observations should suffice of itself to show that the phenomena of Jupiter's cloud-laden atmosphere are not due to solar action. For the rift itself continued, and the changes affecting it continued whether Jovian day was in progress or Jovian night. For one hundred Jovian days or more, and for one hundred Jovian nights, the great cloud-masses on either side of the rift remained in position opposite each other, slowly wheeling, but still continuing face to face, as their equatorial ends rushed onward at a rate fourfold that of a swift train, even measuring their velocity only by reference to the ends remote from the equator, and regarding these as fixed. Probably the cloud-masses were moving still more swiftly with respect to the surface of the planet below.

[1] Two pictures of this belt, as seen March 12, 1860, and April 9, 1860, will be found in my article on "Astronomy," in the "Encyclopædia Britannica," vol. ii., p. 808.

Of course, it is just possible that a great dark rift, such as I have described, might appear thus to change in position without any actual transference of the bordering cloud-masses. Mr. Webb, speaking of a number of phenomena, of which those presented by the great rift of 1860 are but a few, says that "they prove an envelope vaporous and mutable like that of the earth, without, however, necessarily inferring" (? implying) "the existence of tempestuous winds: even in our own atmosphere, when near the dew-point, surprising changes sometimes occur very quietly: a cloud-bank observed by Sir John Herschel, April 19, 1827, was precipitated so rapidly that it crossed the whole sky from east to west at the rate of at least 300 miles per hour; and alterations far more sudden are conceivable where everything is on a gigantic scale." It does not seem to me altogether probable that more rapid alterations would affect cloud-banks covering millions of square miles than occasionally affect terrestrial cloud-banks covering perhaps a few tens of thousands of square miles; on the contrary, as small terrestrial clouds change relatively in a far more rapid way than large ones, and these than cloud-masses covering a county or a country, so it would seem that the changes affecting our largest cloud-layers would be relatively far more rapid than those affecting cloud-masses which could (many times over) enwrap the whole frame of this earth on which we live. But apart from that, and apart also from the important consideration that all such processes as evaporation and condensation, so far as the sun brings them about, should proceed far more sluggishly in the case of a planet like Jupiter than in that of our earth, which receives some twenty-seven times as much heat from the sun (mile for mile of surface), it is utterly incredible that precipitation should have occurred so steadily and swiftly along one edge of the great rift, and condensation—with such exactly equal steadiness and swiftness—on the opposite edge, that, while the rift as a whole shifted its position during a hundred Jovian nights and days at the rate of 150 miles per hour, its sides should nevertheless remain parallel all the time. Such processes may be spoken of as possible, in the same sense that it is possible that a coin tossed fifty times in succession should always show the same face; but we do not reckon such possibilities among scientific contingencies.

But the motion of great rounded masses in the atmosphere of Jupiter is still more decisive as to the existence not only of a very deep atmosphere, but also as to the swift motions taking place in that atmosphere.

I would, in the first place, note that the very existence of belts in the Jovian atmosphere, and especially of variable belts, implies the great depth at which the real surface of the planet must lie below the visible cloud-layers. Atmospheric belts can only be formed where there are differences of rotational velocity. In the case of our own earth we know that the trade-wind zone and the counter-trade zone

owe their origin to the difference of absolute rotational velocity between the equatorial parts of the earth and parts in high latitudes. In the case of Jupiter the difference of this kind is not sufficient to account for the observed belts — partly because there are many, partly because they are variable, but principally because Jupiter is so much larger than the earth that much greater distances must be traversed in passing from any given latitude to another where the rotational velocity is so many miles per hour more or less. Combining with these considerations the circumstance that the solar action which causes the atmospheric movements from one latitude to another in the case of our earth is reduced to one twenty-seventh part only of its terrestrial value in the case of Jupiter, we must clearly look to some other cause for the difference of absolute rotational velocity necessary to account for the belts of Jupiter.

Now, it seems to me that we are thus at once led to the conclusion that the cloud-masses forming the belts of Jupiter are affected by vertical currents, up-rushing motions carrying them from regions nearer the axle, where the absolute motion due to rotation is slower, to regions farther from the axis, where the motion due to rotation is swifter, and motions of down-rush carrying them from regions of swifter to regions of slower rotational motion. This view seems certainly encouraged by what we find when we come to study more closely the aspect of the Jovian belts. The white spots—some small, some large—which are seen to form from time to time along the chief belts present precisely the appearance which we should expect to find in masses of vapor flung from far down below the visible cloud-surface of Jupiter, breaking their way through the cloud-layers, and becoming visible as they condense into the form of visible vapor in the cooler upper regions of the planet's atmosphere. Then, again, the singular regularity with which in certain cases the great, rounded white clouds are set side by side, like rows of eggs upon a string, is much more readily explicable as due to a regular succession of up-rushes of vapor, from the same region below, than as due to the simultaneous up-rush of several masses of vapor from regions set at uniform distances along a belt of Jupiter's surface. The latter supposition is indeed artificial and improbable in the highest degree, and in several distinct respects. It is unlikely that several up-rushes should occur simultaneously, unlikely that regions whence up-rush took place should be set at equal distances from each other, unlikely that they should lie along the same latitude parallel. On the other hand, the occurrence of up-rush after up-rush from the same region of disturbance, at nearly uniform intervals of time, is not at all improbable. The rhythmical succession of explosions is a phenomenon, indeed, altogether likely to occur under certain not improbable conditions—as, for instance, when each explosion affords an excess of relief, if one may so speak, and is therefore followed by a reactionary process, in

its turn bringing on a fresh explosion. Now, a rhythmical succession of explosions from the same deep-rooted region of disturbance would produce at the upper level, where we *see* the expelled vapor-masses (after condensation), a series of rounded clouds lying side by side. For each cloud-mass—after its expulsion from a region of slow, absolute, rotational motion, to a region of swifter motion—would lag behind with reference to the direction of rotational motion. The earlier it was formed the farther back it would lie. Thus each new cloud-mass would lie somewhat in advance of the one expelled next before it; and if the explosions occurred regularly, and with a sufficient interval between each and the next to allow each expelled cloud-mass to lag by its own full length before the next one appeared, there would be seen precisely such a series of egg-shaped clouds, set side by side, as every careful observer of Jupiter with high telescopic powers has from time to time perceived.[1]

That these egg-shaped clouds are really egg-shaped—not merely oval in the sense in which a flat, elliptic surface is oval—is suggested at once by their aspect. But it is more distinctly indicated when details are examined. It appears to me that considerable interest attaches to some observations which were made by Mr. Brett in April, 1874, upon some of the rounded spots then visible upon the planet's equatorial zone. It will not be thought that I am disposed, as a rule, to place too much reliance upon the observations and theories of Mr. Brett, seeing that on more than one occasion I have had to call attention to errors into which, in my judgment, he has fallen. For instance, I certainly do not think he has ever seen the solar corona when the sun was not eclipsed, though I have no doubt he saw what he described, which he supposed to be the corona, but which was in reality not the corona. Nor, again, do I accept (though I do not think it worth while to discuss) his theory that Venus has a surface shining with metallic lustre, and is surrounded by a glassy atmosphere; though in that case, again, his description of what he saw may be accepted as it stands, and all that we need reject is his interpretation thereof. In the case of Jupiter's white spots, Mr. Brett's skill as an artist enables us to accept not only his observations, but his interpretation of them, simply because the interpretation depends on artistic, not on scientific, considerations.

"I wish," he says, "to call attention to a particular feature of Jupiter's disk, which" (the feature, probably) "appears to me very well

[1] Webb thus describes the egg-shaped clouds: "Occasionally the belts throw out dusky loops or festoons, whose elliptical interiors, arranged lengthways and sometimes with great regularity, have the aspect of a girdle of luminous, egg-shaped clouds surrounding the globe. These oval forms, which were very conspicuous in the equatorial zone (as the interval of the belts may be termed) in 1869–'70, have been seen in other regions of the planet, and are probably of frequent occurrence. The earliest distinct representation of them that I know of is by Dawes, March 8, 1851, but they are perhaps indicated in drawings of the last century."

defined at the present time, and which seems to afford evidence respecting the physical condition of the planet. The large, white patches which occur on and about the equatorial zone, and interrupt the continuity of the dark belts, are well known to all observers, and the particular point in connection with them to which I beg leave to call attention is, *that they cast shadows*—that is to say, the light patches are bounded on the side farthest from the sun by a dark border shaded off softly toward the light, and showing in a distinct manner that the patches are projected or relieved from the body of the planet. The evidence which this observation is calculated to afford refers to the question whether the opaque body of the planet is seen in the dark belts or the bright ones, and points to the conclusion that it is not seen at all in either of them, but that all we see of Jupiter consists of semi-transparent materials. The particular fact from which this inference would be drawn is, that the dark sides of the suspended or projected masses are not sufficiently hard or sharply defined for shadows falling upon an opaque surface; neither are they sharper upon the light background than upon the dark. The laws of light and shade upon opaque bodies are very simple and very absolute; and one of the most rudimentary of them is that every body has its light, its shade, and its shadow, the relations between which are constant; and that the most conspicuous and persistent edge or limit in this association of elements is the boundary of the shadow—the shadow being radically different from the shade in that its intensity is uniform throughout in any given instance, and is not affected by the form of the surface on which it is cast, whereas the shade is distinguished by attributes of an opposite character. Now, if the dark spaces adjoining the light patches on Jupiter, which I have called shadows, are not shadows at all, but shades, it is obvious that the opaque surface of the planet on which the shadows should fall is concealed; whereas, if they are shadows, their boundaries are so soft and undefined as to lead to the conclusion that they are cast upon a semi-transparent body, which allows the shadow to be seen, indeed, but with diminishing distinctness toward its edge, according to the acuteness of its angle of incidence. Either explanation of the phenomenon may be the true one, but they both lead to the same conclusion, viz., that neither the dark belts nor the bright ones are opaque, and that, if Jupiter has any nucleus at all, it is not visible to us. It is obvious that the phenomena I have described would not be visible at the time of the planet's opposition, and the first occasion on which I noticed it was the night of the 16th of April last."

This reasoning, so far as it relates to the laws of light and shade and shadow, is, of course, altogether sound. Nor are there any points requiring correction which in any degree affect the astronomical inferences deducible from what Mr. Brett actually saw. I may note that somewhat later Mr. Knobel observed the shadow of white cloud-

masses, and, as the shadow had not so much greater a length at that time, two months from opposition, as it had when the planet was much nearer opposition, he infers that the true explanation of the appearance has hardly been found. He appears to have overlooked the fact that the assumption made in the explanation is not that Jupiter has a semi-transparent atmosphere always equally translucent and penetrable to the same depth by the solar rays. When the shadow was shorter than it should have been, had the atmosphere been in the same condition as when Mr. Brett made his observation, it is probable that a layer of clouds interrupted the rays, and thus the shadow was much closer to the cloud-mass throwing it than it would have been had that layer not been there. Mr. Knobel's paper contains very striking evidence of the variability of Jupiter's atmosphere, or rather of the clouds which float in it. "The greater distinctness of the satellites when near the edge," he says, "is a curious phenomenon which has been repeatedly observed by astronomers, but which seems to require explanation." On an occasion described "the second satellite transited a dark limb which was" (seemed) "most dark near the centre, and fainter toward the edge, yet the satellite was almost invisible when on the darkest part of the belt, and was bright and distinct when the background of the belt was faintest." This practically proved that on the occasion in question the dark, central part of the belt seemed darker than it really was by contrast with the bright belts on either side, while the edge seemed lighter than it really was by contrast with the dark sky on which the planet was projected. In reality the part near the edge must have been darker than the part near the middle, or the satellite could not have appeared brighter when near the edge. No doubt the darkness near the edge (which, by-the-way, my friend Mr. Browning tested photometrically, and demonstrated, at my suggestion, eight years ago) was due to transparency, the darkness of the sky beyond being to some degree discernible through the edge. But this transparency is not always to be observed to the same degree, or through the same extent of Jovian atmosphere as to depth. Mr. Knobel proceeds, illustrating this the more effectively that he does so unintentionally: "The third satellite, on March 25, 1874, appeared as a dark spot when in mid-transit, and on nearing the edge appeared as a bright spot without trace of duskiness. But on March 26, 1873" (observe the difference of years), "the fourth satellite made the whole transit as a dark spot, and was not perceptibly less dark at egress than in mid-transit."

It appears to me demonstrated by the evidence thus far noted that in a semi-transparent atmosphere of enormous depth, surrounding Jupiter, there float vast cloud-masses, sometimes in layers, at others in irregular heaps, at others having well-rounded forms. These cloud-masses undergo sometimes remarkable changes of shape, often forming or disappearing in a very short time, and thus indicating the infe-

rior activity of the forces at work below them—in other words, the intense heat of Jupiter's real globe. As to the actual depth of the semi-transparent atmosphere in which these cloud-layers and cloud-masses float, it would be difficult to express an opinion. We do not know how many cloud-layers there are, how thick any cloud-layer may be, how great may be the depth of the vast rounded masses of cloud whose upper surface (that is, the surface remotest from Jupiter's true surface) we can alone see under favorable conditions. But we can indicate a minimum than which the atmosphere's depth is probably not less; and, from all the observations which I have examined as bearing on this point, I should be disposed to assign for that minimum at least 6,000 miles. I am strongly of opinion that in reality the depth of the Jovian atmosphere is still greater. I cannot doubt that Jupiter has a solid or liquid nucleus, though this nucleus—glowing, as it must be, with a most intense heat—may be greatly expanded; yet I should conceive that, with the enormous attractive power residing in it, containing as it must nearly the whole mass of the planet, its mean density cannot be less than that of the earth. Now, a globe of the mass of Jupiter, but of the same mean density as our earth, would have one-fourth of Jupiter's volume—the mean density of Jupiter, as at present judged, being equal to one-fourth that of the earth. The diameter, therefore, of such a globe would be less than the present diameter of Jupiter, in the same ratio that the cube-root of unity is less than the cube-root of 4, or as 1 is less than 1.5874. Say, roughly (remembering that the atmosphere of Jupiter must have a considerable mass), the diameter of Jupiter's nucleus would, on the assumptions made, be equal to about five-eighths of his observed diameter, or to about 53,000 miles. This is less than his observed diameter by about 22,000 miles, so that the radius of his nucleus would be less than his observed radius by about 11,000 miles—which, therefore, would be the probable depth of his atmosphere.

But we have still to consider the velocities with which rounded masses of cloud travel in the very deep atmosphere of Jupiter. "There is clear evidence," I have pointed out in the article "Astronomy" of the "Encyclopædia Britannica," "that spots on Jupiter are subject to a proper motion like that which affects the spots on the sun. Schmidt, in No. 1,973 of the *Astronomische Nachrichten*, gives a number of cases of such proper movements of spots, ranging in velocity from about seven miles to about 200 miles an hour. It may be noted, also, that from a series of observations of one spot, made between March 13 and April 14, 1873, with the great Rosse reflector, a period of 9 h. 55 m. 4 s. was deduced, while observations of another spot in the same interval gave a rotation period of 9 h. 54 m. 55.4 s." The actual difference of velocity would depend in this case on the actual latitudes of the two spots, which were not micrometrically measured. Taking 200,000 miles as about the circumference of a

parallel of latitude passing midway between the spots (only a very rough calculation need be made), we should find that in a period of one rotation, or, roughly, of ten hours, one spot gained on the other about 51 seconds, or, roughly, about $\frac{1}{100}$ part of a rotation—that is, in distance (dividing 200,000 by 700) about 286 miles in ten hours, or nearly 29 miles an hour.

We have, however, instances of yet greater relative proper motion among cloud-masses. One of these cases I proceed to consider at length:

In June, 1876, two spots were visible upon the disk of Jupiter, so distinct and isolated as to be well adapted for measurement to determine the rate of the planet's rotation. Mr. Brett, observing them first as illustrative of the phenomenon to which he had called attention in 1874, turned his attention afterward to their rate of motion. He would seem not to have been aware of the fact that the proper motion of bright spots and other markings on Jupiter was already a recognized phenomenon; for he asks whether his "observations of these spots, forming a series extending over a period of 286 hours 20 minutes, afford evidence of proper motion, or whether, on the other hand, they tend to cast any doubt on the accepted rotation of the planet." However, his observations are all the freer from the bias of preconceived opinions. "There were several peculiarities about these two spots," he says, "which seemed to me to give them an eminent claim to attention. They occurred very near to the equator, and were very well defined, and free from entanglement with other markings—an advantage which they have maintained with singular uniformity throughout the period mentioned; but the special peculiarity to which attention is asked is, that during an interval of five days they remained in the same relative position without any variation whatever. Their stability in respect of latitude during those five days is undoubted; but the question is, whether or not they were equally stable in longitude. This remark only applies to the first five days of the series, because at the end of twelve days a certain deviation was obvious. The distance between the two spots occupied about 42° of Jovian longitude, or about 33,000 miles. Their diameter is nearly equal, being estimated at about one-fourteenth of the planet's diameter, or 6,310 miles." The interval of time between these first two observations "was 119 hours, that is to say, twelve rotations of the planet according to Airy's determination, during which time their distance apart and their latitude remained constant." Between the first and second observations the two spots had gained "44 m. 6 s. in time. Assuming Airy's rotation, viz., 9 h. 55 m. 21 s., the spots have gained on the planet's surface at the rate of 4 m. 2 s. in each revolution."

Between the second observation and the third "there was an interval of seven days, or seventeen rotations of the planet; and the

same two spots turn up again somewhat earlier than the calculated time. It unfortunately happens," proceeds Mr. Brett, "that on this occasion their configuration had undergone some change; but their dimensions and the distance between them remain very much as before. The most important circumstance respecting them is, that their rate of progress shows a certain acceleration." The change, however, in these seven days, is not such as to permit us to believe that the same pair of spots was under observation. *If* so, a change in latitude much more remarkable than the change in longitude had taken place; for the one which was the most northerly by about 6,000 miles at the beginning of the seven days was the most southerly by nearly the same amount at the end of that period. Considering that in the five days between the first and second observations no change of latitude took place, it may fairly be doubted whether a change of the kind, and so rapid, amounting, in fact, to nearly 900 miles per day, could have taken place in the interval. Proper motions in latitude may indeed be regarded as not less likely to occur in the case of Jupiter than in that of the sun, where they certainly sometimes occur; but all the observations hitherto made on Jupiter assure us that, in his case as in the sun's, proper motions in latitude would be very much slower than proper motions in longitude. We must be content with the evidence of proper motion afforded by the first five days of observation. (The fourth observation only followed the third by about twenty minutes.)

Now, taking this evidence as it stands, and making fair allowance for probable error in an observation of the sort, we may consider that during the 119 hours the two spots were gaining on the estimated rotation-period of the planet by about four minutes per rotation. As they both lie on the equatorial belt, we may take the circuit accomplished by each at about 267,000 miles, or, say, their rate at about 270,000 in ten hours, or 27,000 miles per hour. Hence, the distance traversed in four minutes would be about 1,800 miles, which would be about the gain per rotation. One-tenth of this, or 180 miles, would be the hourly gain, as compared with the estimated rotation-rate. Mr. Brett takes the least proper motion at 165 miles per hour.

He points out justly that the rotation-rate has been derived from observations of some such spots. So that in reality the only inference we can form is, that the rotation-rate derived from some spots is different from the rotation-rate derived from others, and that some spots (if not all) are certainly not constant in position with respect to the solid nucleus of the planet. That the spots observed by Airy, Mädler, and others, should have indicated a slower rate of rotation than those observed by Mr. Brett, may fairly be ascribed to the fact that the former were at some distance from the equator, while the latter were nearly equatorial. For matter thrown up from the equatorial parts of the true surface of the concealed planet would manifestly

differ less in velocity from the superincumbent atmosphere into which they were driven than would masses expelled from higher latitudes. (It is probable that the same explanation applies also in the case of the sun.)

This conclusion, that the spots of Jupiter have rapid rates of relative motion, would of itself be of singular interest, especially when we remember that the larger white spots represent masses of cloud 5,000 or 6,000 miles in diameter. That such masses should be carried along with velocities so enormous as to change their positions relatively to each other, at a rate sometimes of more than 150 miles per hour, is a startling and stupendous fact. But it appears to me that the fact is still more interesting in what it suggests than in what it reveals. The movements taking place in the deep atmosphere of Jupiter are very wonderful, but the cause of these movements is yet better worthy of study. We cannot doubt that deep down below the visible surface of the planet—that is, the surface of its outermost cloud-layers—lies the fiery mass of the real planet. Outbursts, compared with which the most tremendous volcanic explosions on our earth are utterly insignificant, are continually taking place beneath the seemingly quiescent envelope of the giant planet. Mighty currents carry aloft great masses of heated vapor, which, as they force their way through the upper and cooler strata of the atmosphere, are converted into visible cloud. Currents of cool vapor descend toward the surface, after assuming, no doubt, vorticose motions, and sweeping away over wide areas the brighter cloud-masses, so as to form dark spots on the disk of the planet. And, owing to the various depths to which the different cloud-masses belong, and whence the up-rushing currents of heated vapor have had their origin, horizontal currents of tremendous velocity exist, by which the cloud-masses of one belt or of one layer are hurried swiftly past the cloud-masses of a neighboring belt, or of higher or low cloud-layers. The planet Jupiter, in fact, may justly be described as a miniature sun, vastly inferior in bulk to our own sun, inferior to a greater degree in heat, and in a greater degree yet in lustre, but to be compared with the sun—not with our earth—in size, in heat, and in lustre, and, lastly, in the tremendous energy of the processes which are at work throughout his cloud-laden atmospheric envelope.

Since the above article was written, news has been received by the Astronomical Society that Mr. Todd, a well-known observer of Adelaide, New South Wales, has been able to trace the motions of satellites behind the parts of the planet near the edge, or, in other words, *through* those parts of the planet's atmosphere which have hitherto been regarded as belonging to the mass of the planet itself.

TOADSTOOL-EATING.

By JULIUS A. PALMER, Jr.

I DO not mean in this article to consider the origin, reproduction, nature, and extent of the family of Cryptogamous plants called Fungi; for I do not claim the culture of the scientist, or the disinterested enthusiasm of the naturalist. "Art for art's sake" is not my war-cry. I propose to detail in popular language the experiences of an amateur toadstool-eater who desires to encourage personal investigation of a neglected subject.

Not long since, a course of lectures was announced on "Fungi." My call for circulars and tickets revealed the fact that the lecturer proposed to explain all about smut in distinction from potato-rot; the difference between blue-mould, black-mould, and white-mould, was also to be clearly defined, for which purpose a microscope of wonderful power had been provided. It seemed to me that, after people were able to tell healthful food from certain poison, it would be in place to give them a popular course on microscopic organisms.

Three years ago, I was detaching a large fungus from the famous Liberty-Tree on Boston Common. An over-cautious stranger tapped my shoulder and said, "My friend, that is not a mushroom!"

"Now that looks to me like a big toadstool," exclaimed another by-stander.

"Every mushroom is a toadstool, and every toadstool is a mushroom," I replied, and I repeat the answer here. You might as well call a beet a "vegetable," and every other representative from the garden a "plant," as to consider one fungus a "mushroom," and all others of a thousand species "toadstools."

Yet, people cannot be blamed for ignorance where there are so few sources of information. The difficulties experienced by the amateur can scarcely be overrated. Excepting the writings of Dr. Curtis, of South Carolina, I have not seen an original contribution to American literature on this obscure topic. Even Dr. Curtis (in a very interesting correspondence with Charles James Sprague, deposited at the rooms of the Boston Society of Natural History) gives little information regarding toadstools, devoting most of his letters to the revelations made by the microscope. I, however, procured from London the works whose titles I give in the note at the end of this paper, and began the study of fungology as a science.

Still, discrepancies and obscurities will confront the student. The descriptions are by no means exact. All these authorities describe fungi of foreign parts, i. e., not necessarily American species. The classification is not even harmonious, as the generic names of the different species vary with leading authorities, from the time of Sow-

erby to the present. When you have placed a specimen in the proper family, you have not in any way defined its quality, since one mushroom may be esculent, and its twin brother poisonous. Yet, the work of Berkeley is a book easily procured, and, having a number of colored plates, is readily understood by persons with botanical tastes. Such will find no study more fascinating. It is surprising how quickly the hand and eye acquire a delicacy in analysis, impossible to communicate in words. This talent is essential. No one should attempt to gather mushrooms who has not the power to fix in his mind the exact characteristics of any specimen, so as not to be in the least danger of confounding it with its nearest neighbor.

The student must sweep the brain clear of various charms and traditional lore. There is no magical way of identifying good mushrooms; no infallible test for healthful varieties. Here are some specimens of newspaper paragraphs:

"Every mushroom," says one (meaning every edible mushroom), "should peel like a potato."

Agreed, but nearly all the fungi peel readily.

"But the stem ought to come out like an umbrella-handle."

Whole classes (many of them noxious) have free gills, which is the only reason why the stem leaves the cap so easily.

Then, on the negative side, you will hear such attempts at classification as the following, taken from a widely-circulated weekly:

"As a general rule, all found in damp, dark places, or on decaying animal matter, are poisonous. Those that have a very thin cap, or the stem growing from the side instead of the middle, should be avoided. All milky mushrooms, with the single exception of the orange milk-mushroom, are extremely dangerous. So also are those which have the gills of equal length, those which run speedily into a dark, watery liquid, which taste bitter or burn the mouth, *or have a fetid, sickly smell.* If a mushroom turns a variety of colors when bruised, or is marked by the trail of a snail, it can under no circumstances be eaten."

Excepting, perhaps, the phrase I have italicized, the above is a tissue of misapprehension. Damp, dark places produce the very best mushrooms. The edible champignon (*Marasmius oreades*) has a very thin cap. The elm-tree mushroom (*Agaricus ulmarius*) has an eccentric stem. The brown milk-mushroom (*Lactarius volemum*) is unquestioned, and several others are doubtless esculent. A whole family (*Russulæ*) have equal gills. The maned mushroom (*Coprinus comatus*), most delicious, and easily recognized, turns to ink without the addition of any fluid. The honey-colored mushroom (*Agaricus melleus*) is very acrid raw, as are also others, equally harmless when cooked. Several esculent Agarics turn red when bruised, and many edible Boleti change color. I never saw a snail on a mushroom. Presuming that the writer means to refer to slugs, I would add that

I have often cut them out of mushrooms, rejecting only the part they had spoiled.

I have given but one example of each inconsistency, but they might be multiplied almost indefinitely. Then comes your believer in charms: dropping salt on the mushroom to see if it turns black or yellow, or stirring them with a coin spoon to watch for evidences of discoloration. Another rejects all which grow from wood. But no test of any kind, in form, color, or basis of growth, will distinguish healthful from harmful fungi.

"What, then?" despairingly asks an inquirer—"what, then, can be done?"

Exactly what is done in every other department from domestic economy to high art. How does Mr. Jarves tell the difference between a painting by Leonardo da Vinci and one by Guido Reni? How could you explain (to one who had never seen either) the difference between a hyacinth-bulb and an onion? From essays on the early painters, you draw conclusions which enable you to distinguish at sight the works of two artists. In kitchen-lore, the child acquires distinctions with its earliest lessons at the mother's apron-string. Only by these two means can practical knowledge of the kingdom of Fungi be increased: first, exact scientific analysis; second, the circulation of arbitrary, traditional information, such as saying to ignoramus:

"There, sir, that is an elm-tree mushroom; mark it well: whenever you find one just like it on your elm, eat it."

With a view of encouraging research, I shall make an attempt at an original but very limited classification, and also describe a few varieties of mushrooms. The first distinction is in the nature of the surface bearing the reproductive bodies or spores. Pick the next toadstool you find; look under the top or cap. You will observe one of four things:

1. There is a series of thin plates set on their edges running in to a common centre, like the spokes of a wheel. The spokes are called the gills; the stem corresponds to the hub. This is the largest family of mushrooms, the *Agaricini* or *Agarics*.

2. In the place of gills, your specimen may have a substance resembling fine sponge. It is then a pore-bearing mushroom, generically a *Polyporus*. Supposing the stem to be distinctly defined, of ordinary length, and the pores or tubes easily separable from each other, it is a *Boletus*.

3. Instead of the sponge, you may find a number of small points or spines. It belongs then to the teeth-bearing fungi, generically the *Hydnei*.

4. When you invert the mushroom, you may find neither gills, pores, nor teeth. It may be globular. In the three other classes, the spores are borne externally; here they are inclosed. If young, the

skin is filled with a substance, white, yellowish, purple, or black. If old, the contents are discharged in dust at a smart squeeze. It is a Puff-ball.

As the object of this article is to interest those having no knowledge whatever of the subject, I shall not allude to other families. It is probable that your toadstool will come within one of these four grand divisions. If not, select another at once.

The puff-balls are the safest mushrooms for the beginner. When you find one, with a smooth skin, perfectly white inside, it is the giant puff-ball (*Lycoperdum giganteum*) in an infantile state. The color of the skin varies from pure white to a shade almost black. If the knife leaves a stain of yellow, it is too old to eat. Otherwise, you may eat it without fear. There are several smaller varieties, which my wife and I eat indiscriminately.

I believe all white puff-balls may be safely used if cooked at once. They change very rapidly after gathering, and should only be eaten in their freshest state. There is no poisonous fungus resembling them.

The teeth-bearing toadstools are also safe fungi for the experiments of the amateur. I have found only one variety, but Smith says all the species of any size enjoy a good character. The spreading hydnum (*Hydnum repandum*) is usually yellow, sometimes reddish, always firm-fleshed; stem deformed, indistinct, or eccentric; and one side of the disk, or top, is frequently much higher than the point diametrically opposite. The peculiarity of the teeth, or spines (which in young specimens easily rub off), is enough to distinguish it.

The *Boleti* can only be confounded with their twin brothers, the *Polyporei*. The latter grow mostly on wood, with abortive stems, while the boletus of the edible kind grows from the ground, has a distinct stem, and the tubes of the sponge are easily separable from each other. If these tubes or pores are brown, yellowish, or greenish, the top being russet-color, or any shade of brown, and on cutting the flesh it remains white, it is an edible, or at least a harmless, variety. If the plant is brilliant-colored, red or yellow, or turns blue when bruised, it is best to reject it. If the tubes are red at the orifice, it is doubtless poisonous.

The *Agaricini* (those with gills) cannot be thus generalized, and I regard them as the least safe for the amateur, although it is to this class that the celebrated individual honored by English-speaking people with the title of "a mushroom" belongs. How can I describe this species, it varies so widely with its circumstances?

Two varieties, the meadow-mushroom (*Agaricus campestris*) and the horse-mushroom (*Agaricus arvensis*), run into each other by intermediate types so closely that professional cooks and gardeners may be forgiven that they entirely ignore any difference between them. There is a theory that the horse-mushroom is propagated from spores

of the meadow-mushroom after these latter have passed through the system of the horse.

At first, this mushroom resembles a puff-ball, but it soon discloses under the cap a veil or web, which ruptures and exposes the gills, free from the stem, with a faint shade of pink. This color deepens more and more, passing through purple into black. When pink, the ring around the stem is quite perfect, but I have found older specimens with not a trace of ring or veil. The top is every shade from pure white to deep brown; and, altogether, I can only advise the amateur to have one identified by an expert, if possible. Though difficult to describe, the taste and smell are so peculiar to the species that there is not much danger of deception when once you have made their acquaintance.

The most easily-recognized agaric is the maned mushroom (*Coprinus comatus*). When fit for food, it is the shape of a turtle's egg; that is, ovate, but alike at each end. The top is brown and smooth, but toward the earth the outer skin ruffles up, making a white mane or fringe of concentric layers around it. The stem is hollow, and on being cut appears, as it cooks, like macaroni. There is a ring round the stem, which is movable in the well-developed plant. Very soon after acquiring its growth the points of the gills turn black, sometimes running into pink; then it opens umbrella-like, and melts into an inky fluid. This was the first fungus we dared to eat on our own recognition, and has no poisonous counterpart. It should never be eaten either stale or having black gills, or when found around dust-heaps or other offal.

The second experiment was made on the elm-tree mushroom (*Agaricus ulmarius*). It grows only in fall on the elm, has a thick, solid stem (sometimes set in the side), broad white gills, firm white flesh, and a light-yellow top, at first smooth, finally spotted and cracked. Older, the gills turn yellow and the top very leathery. I know of no other large fungus with gills and white flesh growing from the elm. It is most common in a cleft, or where a limb has been sawed off, and often reappears yearly in the same spot.

The family of the *Russulæ* is quite safe for beginners. In the common mushroom you will notice the gills are pliable; the flesh also can be bent without breaking. The milk-mushrooms and the *Russulæ* are very brittle; the gills do not mat down like the horse-mushroom, or the elm-tree mushroom; they break into small pieces, while the whole fungus snaps suddenly on being bent. If milk or juice comes, I advise the amateur to reject the specimens. A novice should not attempt to cook them. If they are perfectly dry, taste a small piece. If it is not an edible russula, it will be likely to bite and sting the tongue, while all the esculent varieties of the genus are tasteless, mild, or with the flavor of chestnuts. There is one very common variety (*Russula alutacea*) with a bright-red top, buff-colored

gills, and stout, short stem. But two others (*Russula emetica* and *Russula rosacea*) resemble it so closely that, to this day, as I wash them, I invariably put a little piece of the stem of each into my mouth, in order to avoid all possibility of mistake.

I am in hopes to establish the truth of this theory: namely, that no fungus which, unspiced, being plainly cooked with dry heat, commends itself to the taste, can be dangerous to human life.

I advance this proposition with hesitation, because many people have so little sense in such matters. Mushrooms are mixed with gravies, fried in batter, simmered in fat, seasoned with black pepper or parsley-leaves, and their delicate flavor destroyed by compounding them with other food. The cook, thereby, disguises the very alarm which Nature has placed at the gateway. One of the most common signs of hurtful fungus is a stinging sensation affecting the tongue but little, the throat and tonsils more, and probably having the most effect upon the stomach and bowels. Let the mushroom absorb fat enough to cover this, or disguise the taste either by spice or by mixing one variety with another, and you may easily eat enough of a poisonous fungus to cause death.

Julie and I have tested perhaps forty varieties of toadstools; of these, we eat regularly, whenever found, considerably more than one-half, and are daily making additions to our bill of fare. Yet, I would not have the reader infer that we act carelessly. In whatever cause, reckless disregard of consequences is *not* bravery, although no two elements are oftener confounded. After tracing a specimen to its family, we broil it with the addition of salt and butter (no pepper), and eat a small piece on an empty stomach. We then increase the quantity in successive experiments until we feel perfectly safe, or experience unpleasant sensations. Usually, the non-edible fungus discloses its character over the charcoal: nauseous slime weeps from the stem, a grassy and disagreeable odor arises as it heats, or, on being tasted, there is no desire to take another mouthful. The intuition of woman, the cleverness with which the feminine mind grasps at an idea over which the stronger sex will reason mentally for hours, is nowhere more valuable than in the pursuit of this study.

We have never yet been deceived into making a meal of poisonous fungus. From the sparkling coprinus (*Coprinus micaceus*), a little toadstool very common about old stumps, and one or two other kinds, we have received evidence that condemned them as esculents. But we were once poisoned by some common mushrooms contaminated by being sent in a box containing a large number of another kind. The latter (*Coprinus deliquescens*) were in a state of decomposition. They eventually turn to ink, independent of contact with any fluid substance. In passing, I would say that the manuscript of this article is written with the result of such deliquescence. We had scarcely swallowed the edible ones before we felt the effects of the poison.

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Our symptoms were not unlike those exhibited in a person using tobacco for the first time. Dizziness, nausea, purging, perspiration, with alternate cold spells, all passed over us within an hour, so rapid is the effect of the mushroom-virus. Two wineglasses of whiskey and sweet-oil (equal parts) neutralized the poison, and in a few hours we were no worse for the experience.

I would prescribe this remedy in all cases rather than the use of emetics. Omit the whiskey, if you please, or substitute vinegar for spirits, but take sweet-oil liberally in case of a mistake. I believe the Italians eat many dangerous fungi with impunity, because, when fresh, their properties are changed by sweet-oil; preserved, they are neutralized by pickle. Either of these elements renders harmless the peculiar alkali, to a superfluity of which mushrooms owe their noxious qualities.

We must use the same discretion daily employed in selecting other food. Who would willingly eat tainted meat? Is it so very uncommon to find a goose or duck too strong to be palatable? Who has not been poisoned by bad oysters, stale fish, or overripe fruit?

Because many mushrooms do not agree with the human system, it does not follow that they are deadly poisons. I have friends who do not pretend to distinguish varieties, but eat whatever has an appetizing flavor. (I do not consider this safe ground, because the inability to identify any one variety is doubtless the cause of many cases of poisoning.) Yet, although they claim to have made their breakfast from such obscurely known kinds as that which I afterward classified as the smeared cortinarius (*Cortinarius collinitus*), I have never known them to acknowledge any other sensation than an intense desire to hunt for more. Julie and I had one day eaten plentifully of the honey-colored mushroom (*Agaricus melleus*). On looking it up in Greville, a well-known Scotch authority, I found the following notice: "This species is said to be freely eaten on the Continent; at least Fries quotes the authority of Trattinick for the fact. But, on the other hand, Persoon gives it a bad character. In this he is supported by Paulet, who tried its effect upon a dog. The poor animal died twelve hours after receiving the poisonous fungus."

Notwithstanding such a warning, it continues to be a favorite article of diet with us to-day. I think it may be noxious raw, but that the heat kills the virus. It must be remembered that toadstool-eating is by no means an exact science. Fungus-eaters are daily making discoveries. Twenty years ago the two leading authorities of England and America, Berkeley and Curtis, considered the *Coprinus comatus* poisonous.

There are but two ways in which it is proper to cook mushrooms. By far the majority are best broiled on a fine-wire gridiron. They should be sprinkled with salt and (if the species is well known as an esculent) red pepper, buttered as the fire browns them. Otherwise,

stew them in milk, exactly as you would make an oyster-stew. The elm-tree mushroom, the honey-colored mushroom, and any others tasting raw of grass or trees, are only good broiled. The meadow-mushroom, horse-mushroom, or coprinus, are excellent cooked either way. There is no doubt of the wholesome character of esculent fungus. During the season, we eat them at our table three times a day; sometimes of a half-dozen kinds at a meal. We never enjoy better digestion than during toadstool-time. They furnish a natural alkali which in some systems is greatly needed.

We also dry them for use in winter. The Chinese and Japanese make dried fungus a very general article of diet. I speak here from personal acquaintance with their habits, acquired by a residence in San Francisco and Honolulu, as well as in their native land. No better substitute for meat than fungus can be found. Neither its odor when cooking, nor the gravy it makes, resembles any form of vegetable food. This is but natural, since the plant absorbs oxygen from the air, after the manner of animals.

Mushrooms grow above the ground, like any other plants. I have carefully watched all kinds, both in a natural state and when raised in my own closet. The common mushroom (supposed to spring up in a night, and which, says vulgar error, must be gathered with the dew on it) takes about ten days to mature from a button the size of a pin-head to a disk three or four inches in diameter, although most of this time the cap is just beneath the soil. This is the average period needed in acquiring perfection by other kinds, although some, as the *Coprinarii*, do not consume half that time.

Note.—Outlines of British Fungology, by Rev. M. J. Berkeley. London: L. Reeve & Co., 1860.

Handbook of British Fungi, by M. C. Cooke. London: Macmillan & Co., 1871.

A Plain and Easy Account of British Fungi, by M. C. Cooke. London: Robert Hardwicke, 1871.

Mushrooms and Toadstools. Illustrated with Two Large Charts. By Worthington G. Smith. London: Robert Hardwicke, 1867.

The Esculent Funguses of England, by C. D. Badham. London: L. Reeve & Co., 1870.

Fungi: their Nature and Uses, by M. C. Cooke. Edited by Rev. M. J. Berkeley. New York: D. Appleton & Co., 1875.

SKETCH OF PRESIDENT BARNARD.

AMONG the promoters of science and liberal culture in our time, few men have labored more efficiently and successfully than the present versatile and accomplished President of Columbia College. Although Dr. Barnard has done his share of original scientific work, it is not claimed for him that he has made any great discoveries;

nor could this be justly expected of a man whose life has been so absorbed in the work of educational reform, the progress of scientific culture, the organization and administration of collegiate institutions, and the furtherance of those higher measures and agencies of intellectual improvement which are never carried out except through the executive force and indomitable perseverance of a few men who are specially constituted for such tasks. Dr. Barnard has been untiringly busy in these important spheres of activity for nearly half a century, and seems still in the prime and vigor of his powers, and the meridian of his public influence.

Frederick Augustus Porter Barnard was born in Sheffield, Massachusetts, in the year 1809. He was educated at Yale College, where he graduated in 1828. He began his career as teacher by taking the position of tutor in that institution in 1829. In 1831 he went to Hartford, and engaged as instructor in the Asylum for the Deaf and Dumb; and, becoming interested in this branch of teaching, he subsequently pursued it in the Deaf and Dumb Asylum of New York. He afterward published an "Analytic Grammar, with Symbolic Illustrations," based upon a system he had originated for teaching the deaf and dumb, and which is still used in institutions devoted to their education. Dr. Barnard early chose the South as his field of labor, and in 1837 became Professor of Mathematics and Natural Philosophy in the University of Alabama, at Tuscaloosa, and subsequently took the chair of Chemistry in the same institution, which he held until 1854. The same year he took orders in the Protestant Episcopal Church. In 1854 he became Professor of Mathematics, Astronomy, and Civil Engineering, in the University of Mississippi, at Oxford, was elected its president in 1856, and promoted to its chancellorship in 1858. During his long residence at the South, Dr. Barnard devoted himself with great energy to the subject of education, both primary and academic, and advocated liberal and advanced views regarding college polity in several able reports. Never an opponent of classical culture, he freely criticised it, and strongly urged the claims of science to a larger and higher place in modern study than had been hitherto allowed. At the approach and outbreak of the civil war, President Barnard, remaining loyal to the Union, found himself embarrassed in his Southern position, and in 1861 he resigned his chancellorship and his chair in the university, and returned to his native North. In 1862 he was engaged in continuing the reduction of Gilliss's observations of the stars in the southern hemisphere. In 1863 he was connected with the United States Coast Survey, and had charge of chart-printing and lithography. Prof. McCulloch, who occupied the chair of Physics in Columbia College, New York, having left the institution and gone South to take his chances with the Confederate cause, Dr. Barnard became an applicant for the vacant position; but, instead of accepting him for this place,

the trustees of the institution elected him as its president in 1864, which office he still holds. Coincident with his accession to the presidency of Columbia College, an important step was taken by the managers of the institution for the promotion of scientific education by the establishment of the School of Mines, and the appointment of an able faculty to carry it on. This branch of the college has been so well administered as to become a great success. Its facilities for scientific training are ample and well directed, and in the number of its students it is already the rival of the classical department.

Dr. Barnard has written much upon both scientific and educational topics, and done a good deal of important work in connection with the various international expositions of industry, to which he has been commissioned by our Government. His last important literary undertaking has been the editorship of Johnson's "New Illustrated Universal Cyclopædia." He has received many honors from institutions of learning and leading scientific societies, both in this country and abroad, and has been President of the American Association for the Advancement of Science, of the American Microscopical Society, and of the American Institute, New York. The following are President Barnard's most important publications:

In the Journal of Science.

1. Aurora Borealis, 1838.
2. Improvement in Photography, 1842. (This was one of the earliest processes discovered for quickening the sensitiveness of Daguerre's iodized plates.)
3. Theory of Hot-Air Engine, 1853.
4. Modification of Ericsson's Hot-Air Engine, 1853.
5. Elastic Force of Heated Air, 1854. (A series of papers.)
6. Comparative Expansion of Heat in Different Forms of Air-Engines, 1854.
7. Mechanical Theory of Heat, 1854.
8. Examination of the Theory which ascribes the Zodiacal Light to a Ring surrounding the Earth, 1856.
9. The Eclipse Expedition to Cape Chudleigh, Labrador, 1860.
10. Hydraulics of the Mississippi, 1863.
11. Explosive Force of Gunpowder, 1863.

In the Proceedings of the American Association for the Advancement of Science.

12. On the Pendulum, with Description of an Electric Clock with Pendulum perfectly free, 1858.
13. On the Means of preserving Electric Contacts from Vitiation by the Spark, 1859.
14. Extended Report on the History, Methods, and Results of the American Coast Survey, 1859.
15. On the Assumed Identity of Mental and Physical Forces, 1868.

In the Reports of the Smithsonian Institution.

16. The Mathematical Principles of the Undulatory Theory of Light, 8vo, pp. 133, 1862.

In the Transactions of the American Institute.

17. The Metric System—History of the Movement in its Favor, 1871.
18. Theory of the High-Speed, Heavy-Piston Steam-Engine, 1871.

In the American Naturalist.

19. Description of a New Form of Binocular Microscope, 1871.

Published by the Trustees of Columbia College.

20. Essay on the Metric System—Examination of the Objections brought against it, and Discussion of the Values of its Units, with an Appendix on the Unification of Moneys, 8vo, pp. 194, 1872.

Published by the Senate of the United States.

21. Machinery, Processes, and Products of the Industrial Arts, and Apparatus of the Exact Sciences—Report on the Exposition of 1867, 8vo, pp. 669, 1868.

In "Field's Outlines of an International Code."

22. The chapters relating to Money, Weights and Measures, Longitude and Time, and Sea-Signals, 8vo, pp. 86, 1870.

Published by the Public Health Association of the United States.

23. On the Germ-Theory of Disease, 1874.

In the Journal of the General Convention of the Protestant Episcopal Church for 1871—*Appendix.*

24. On the Principles of the Ecclesiastical Calendar, with Concise Rules for finding the Movable Feasts, 1871.

In Johnson's Cyclopædia.

25. Numerous articles on topics in Mathematics, Mechanical and Physical Science, and on miscellaneous subjects scattered through the published volumes, 1874–'75.

Among his educational papers may be mentioned: "Letters on College Government," 1854; "Report on Collegiate Education," 1854; "Art-Culture," 1854; "Improvements practicable in American Colleges," 1855; "University Education," 8vo, pp. 104, 1858; "Relation of University Education to Common Schools," 1858; "Studies best adapted to Early Culture and Preparation for College," 1866; "Elective Studies in College Education," 1872; "Analysis of Statistics of Collegiate Education," 1870; Annual Reports to the Trustees of Columbia College, 1865, *et seq.*—a series; and numerous papers on Deaf-Mute Instruction, 1832–'37.

CORRESPONDENCE.

INSECTS AND FLOWERS IN COLORADO.

To the Editor of the Popular Science Monthly.

UNDER the above heading, in the January number, Mr. Meehan calls for a list of the *Hymenoptera* and *Lepidoptera*, abundant enough to probably act as cross-fertilizers of flowers in the region observed by him—namely, from Denver to Golden City and Idaho Springs, through the South Park to Pike's Peak, thence returning to Denver direct.

In 1871 (the year of Mr. Meehan's observations) I spent the months of June, July, August, and September, entirely in the region mentioned, and devoted my time almost exclusively to the collection and observation of *Lepidoptera*. In no place outside of the tropics have I found a better collecting-ground, at least so far as diurnals are concerned, both as to variety of species and number of specimens. This abundance, however, is chiefly noticeable early in the season, as indicated by the number of specimens I was able to secure in the different months—namely, 1,792 in June, 1,483 in July, 607 in August, and only 43 in September.

Of insects of other orders I collected about 3,800 specimens; but very few of them were *Hymenoptera*, as I devoted only rainy days to the collection of insects other than butterflies. Several species of humble-bees were observed; these did not seem to confine their attention to any particular kind of flower.

At Idaho Springs, about the middle of August, I saw hundreds of *Noctuidæ* attracted by the lights of the hotel, and captured some sixty specimens. A noteworthy fact is that in the Alpine regions many *Noctuidæ* were diurnal in their habits. The most abundant species was *Heliothis Meadii* (Grote); these moths were found flying from flower to flower, or resting upon flowers both above and below the timber-line. The white-lined sphinx (*Deilephila lineata*) was also quite plentiful in some spots, and seemed quite partial to larkspur and similar showy flowers.

Certain diurnals of arctic types positively swarmed on many of the peaks—for example, *Argynnis Helena* (Edwards), and lower down several species of *Melitæa*, *Phyciodes*, and *Argynnis*, were constantly to be found at flowers.

I give a list of the more abundant butterflies, with the number of specimens of each species or genus taken, classing those occurring almost entirely at or above the timber-line as Alpine; those found mostly below 11,000 feet elevation as valley species—the species in the latter class which range above the timber-line to any great extent are designated by an asterisk (*).

Necessarily most of the collecting was done below the timber-line; hence the Alpine species were more abundant in individuals than the recorded number of specimens collected would indicate. None of the species are likely to have been introduced by the agency of man.

ALPINE SPECIES.

Colias Meadii	65
Argynnis (5 species)	150
Chionobas (2 species)	25
Erebia Tyndarus, variety Callias	62
Hesperia near Centaureæ	15

VALLEY SPECIES.

Parnassius Smintheus *	241
Pieris (3 species)	106
Anthocharis (2 species)	79
Colias (5 species)	389
Vanessa, Grapta, etc. (9 species)	138
Argynnis (8 species)	210
Euptoieta Claudia * (very abundant)	52
Melitæa and Phyciodes (8 species)	297
Satyridæ * (7 species)	495
Lycænidæ * (31 species)	835
Hesperidæ	219
Geometridæ and Noctuidæ *	318

THEODORE L. MEAD.

CORNELL UNIVERSITY, *January* 20, 1877.

SINGING IN THE EARS.

To the Editor of the Popular Science Monthly.

MR. EDITOR: Do the minute tones heard in "singing" or "ringing in the ears" have any musical relation to each other?

"Singing in the ears" is a mingling of minute tones, somewhat like the singing of a tea-kettle, caused by undue pressure of the circulation in the head, etc.

In my own case, the minute tones seem to be *octaves*, and *thirds*, and *fifths* apart, forming chords and progressive intervals.

In investigating the relation of music to the physiology of audition, I find this a very important question, demanding a multiplicity of evidence. Will those of your readers who have information on this matter (positive or negative, but *exact*) write to me?

X. Y. CLARK,
BOX 2,260,
SAN FRANCISCO, CALIFORNIA.

FEEDING-HABITS OF WOOD-ANTS.

To the Editor of the Popular Science Monthly.

IN the March number of your journal, page 634, is a notice of the "Singular Feed-

ing-Habits of Wood-Ants," wherein occurs the statement that, if the ants were immersed in water and placed on the ant-hills, they were invariably attacked by other ants as enemies, etc. This action is so at variance with what I have observed, that I will mention an incident which occurred while I was botanizing in Wisconsin last summer. In passing by a large stump I observed that the top was covered with large wood-ants. They were feeding on crumbs of bread left by some school-children. On the stump was a depression, where the ants were in large numbers. Procuring some water from a lake close by, I poured it into the depression, submerging several dozen ants. The most of them swam to the margin; others were in danger of drowning. What was my astonishment to see those who had escaped *rush into* the water, seize their drowning fellows, and drag them to the shore, where they tenderly turned them over until satisfied they were alive, when the rescuers went back and tried to save others! A few were dragged out too late—they were dead. These were turned over, felt of by the antennæ of the rescuers, and left for dead. In no instance was there any appearance of violence to the wet ants by the dry ones. The intelligence shown by these ants was greater than I had ever dreamed they possessed, and since that time I have had a most sincere respect for my lowly fellow-laborers.

E. M. Hale, M. D.

Chicago, *February* 24, 1877.

EDITOR'S TABLE.

MENTAL OVERWORK UNDER THE COMPETITIVE PRIZE SYSTEM.

THE death by suicide, not long ago, of a brilliant student of Cornell University, Emil Schwerdtfeger, at the age of nineteen, has a painful interest in connection with the subject of education. We are glad to see that the case has elicited some wholesome comment on the part of the press, in regard to the influences to which he was subjected, and the system of culture that supplies them; and we think the lesson that has been drawn ought to be enforced upon the public mind in the most pointed and emphatic manner.

It seems that the young man had fallen into a state of hopeless depression, after a course of successful study, in which he had made the most remarkable proficiency in the languages. His mental condition reminds us of that through which John Stuart Mill passed, when about the same age, after being subjected by his father to that long and terrible discipline of acquisition which is so fully described in his autobiography and has been curiously confirmed by a letter lately discovered, written by young Mill at the age of thirteen to Sir Samuel Bentham. After being crammed with knowledge in the most systematic way—dead languages, classical literature, history, mathematics, and political economy—from early childhood, by poring over books, until he became a perfect prodigy of erudition, he passed into a cloud of melancholy, in which his future life seemed vacant and hopeless. All the fountains of impulse that had previously incited him to effort seemed dried up in his gloomy dejection. He went on with his work mechanically, but without interest, while this portion of his life, or what he did in it, was afterward hardly remembered. He subsequently described his case in the following lines from Coleridge:

> "A grief without a pang, void, dark, and drear,
> A drowsy, stifled, unimpassioned grief,
> Which finds no natural outlet or relief
> In word, or sigh, or tear."

He was not free from suggestions of self-destruction which arise in such mental conditions, as we gather from the following remarks: "I frequently asked myself if I could, or if I was bound to, go on living, when life must be passed in this manner. I generally answered to myself that I did not think I could possibly bear it beyond a year." It was unquestionably a case of brain-

exhaustion, brought on by steady, prolonged, and severe mental application, and giving rise to the morbid condition of melancholia. His vigorous constitution, however, rallied and carried him through, although he had several relapses afterward. His education had been conducted as if his mind was a chamber to be packed with knowledge, rather than a force or activity dependent upon an organ of exquisite delicacy, which is liable to be strained, overworked, impaired, and broken down.

The tragical result in the case of Schwerdtfeger was due to two causes, from the operation of which Mill was comparatively exempt: he had slender health, and he was exposed to the artificial, high-pressure competitive system which is now so much in vogue in the sphere of higher education. He was a poor boy, of a highly-sensitive nature, intellectually precocious, and with an unhappy home, from the trouble of which he had only been able to escape through absorption in books and study. At fourteen or fifteen he was employed in an office to translate German works, and displayed such remarkable faculties that a wealthy gentleman thought he would give him a chance by sending him to college. He went to Cornell, at the age of sixteen, and, though not prepared to enter the university, took up his residence with one of the professors, and was quickly qualified for admission. No sooner had he got in than he began at once to be plied with the dangerous stimulation of the competitive prize system. A pecuniary reward was offered for the best essay on the "English verb." Our slender lad went in for it and won the prize and the honor, while yet a freshman, with abundant plaudits for his remarkable production. The distinction thus early achieved had of course to be sustained, and an extrinsic and artificial pressure was thus brought to bear upon the young man, who was thereafter expected to be an honor to the institution. He threw himself with all the premature ambition of a precocious nature into lingual studies—a class of studies that stands highest in the rank of collegiate scholarship, and that, therefore, brings most applause. It must be remembered, also, that the ascendency of these studies has long been defended on the ground that they afford the most available standards of acquisition, or the sharpest means of marking the student's progress; in other words, are best fitted of all subjects for racing and winning honors. Language after language was rapidly acquired. Schwerdtfeger bought a Greek grammar and stuck to it for ten hours a day, as we are informed, getting on with such proficiency that a distinguished Greek professor, from another institution, happening to be there, was set to examining him. After three or four hours of it, the professor declared that he was well prepared to enter the classical course of any college in the country, and was confounded when told that Schwerdtfeger had only begun Greek three weeks before. In languages he was ahead of any student who had ever been in the university. He gave lessons as tutor in Latin, Spanish, German, Greek, French, and Portuguese. Under this intense strain his health, originally poor, grew worse, and he ought then to have at once left the place. There is a moral discipline in such institutions which, if violated, entails expulsion; and it is a serious question whether there ought not to be a sanitary discipline, equally stringent, for the exclusion of students who damage themselves by over-study. But when the boy's health quite gave way under the stimulation of college influence, instead of being sent away, he was struck by a baneful agency from without. The Intercollegiate Literary Association offered prizes before the whole country for the best essay in Latin. The sick boy of Cornell entered into the competition, beat all his rivals, and won the

highest prize. He then lapsed into deeper morbid despondency, made his will, and shot himself through the head with a pistol.

We have here merely another instance, of which there have been thousands before, of the vicious working of that competitive system in our higher educational institutions, which should receive the inexorable reprobation of the community. Prof. Johannot writes to the *Tribune*, in relation to Schwerdtfeger's case, saying that Cornell University neither forces, crams, nor uses class-markings, which is all very well; but how about competitive prizes? Does it forbid these to its students? and, if not, is there no "forcing" here? Schwerdtfeger began and ended at Cornell by gaining prizes. If Schwerdtfeger "came to the institution an exceptional student, with a thirst for knowledge which was an absorbing passion, and had morbid fancies and an inherited tendency toward insanity and suicide;" if he was "fascinated with the life and fate of Chatterton," then the institution that took charge of him is to be all the more condemned for exposing him to the fatal stimulus of competitive prizes.

It is forgotten that we live in an age of excitement—a speculating, gambling, horse-racing age, feverish with political, religious, commercial, and sporting rivalries. All grades of society are infected by it, and the universal interest in it is such that the newspapers are crammed day by day with the details of competitive conflicts in numberless forms, from foot-races up to political campaigns. Against all this our higher education ought to make a stand. But, instead of doing so, the colleges, in various degrees, yield to the general tendency, and, in fact, avail themselves of the competitive spirit in carrying on their work. The pernicious effects of artificial excitements and provocatives are undeniable and notorious. Many have been sacrificed to this forcing system, through constitutional enfeeblement, prostration by disease, and premature death. For the natures upon which it takes effect are just those that are most liable to become its victims. Fatal results may not be produced, but shattered nerves and broken constitutions do follow everywhere upon the competitive prize system, because it is the readily impressible, the impulsive, and the unregulated, that are taken by its lures.

It is a physiological fact of the greatest importance in education that, under the stimulus of intense feeling and factitious excitement, the brain is capable of making rapid and extensive acquisitions, which are, of course, correspondingly transient. The cramming policy rests upon this capability of the brain, and it is this to which the competitive prize system appeals. It bids for immediate, striking, and showy results in acquisition, to be gained by exhaustion of the plastic power of this organ, and that, too, during the period of its growth, when the forces are required for enlargement and advancing organization. It violates this fundamental principle of education: that intellectual acquirement, to be permanent and valuable, must be slow; and that, for healthful mental development, knowledge, like food, must be taken as required by normal appetite, and become assimilated into faculty by the quiet, unforced processes of organic transformation. The protests in recent years against this policy have been many and emphatic, and much has been done to check it; but it will undoubtedly continue so long as partial parents continue to be imposed upon by the shallow parade of examinations, exhibitions, and prize-shows.

The Intercollegiate Literary Association now appears as a new force well calculated to thwart this beneficent tendency. It works by prizes and honors in their most mischievous forms, by blazoning the victories of students through all the newspapers in the land; so that

one might almost infer that the very object of its establishment is to encourage and strengthen the worst feature of educational practice. It is not an organization to improve the colleges by giving encouragement to neglected studies, or by bringing their schemes of instruction into completer harmony with the claims of modern knowledge or the necessities of modern life; but it offers its sensational rewards for proficiency in just those subjects which have long usurped undue attention in the collegiate education. It applies increasing pressure in those directions in which pressure is already excessive. Hence, if there are any students already shaken by struggles to get the leading positions in the colleges, the Association tempts them to come forward and fight it out with each other before the whole country. It will remain true to the end of time that those who sacrifice all the rest of their nature to the attainment of any one object will win it as against those who regard the claims of their whole nature. The Intercollegiate Association bids for the best cases of one-sided development. If a student has sacrificed his bodily health to brilliant scholastic results, the Association wants him for exhibition. Johannot says that Schwerdtfeger, "in preparing for the late intercollegiate contest, made no extraordinary effort;" yet he beat all the healthier fellows out of sight, and the Association gave him a prize for his disease. If it killed him, no matter; that was but an incident. Do not horses often die on the race-course? and are not men often killed in the prize-ring? Aspirants must take their chances. To the earnest protest of a correspondent to its encouragement of the Intercollegiate Association the editor of the *Tribune* replies, "Even if young Schwerdtfeger's death could be directly traced to overwork in connection with the recent competition in this city, we should hesitate before condemning the intercollegiate literary contests." This is a little startling as an illustration of the foothold that sporting ethics has got in the field of education; but we can admire that pluck of opinion which does not recoil from its logical consequences.

THE RELATIVE IMPORTANCE OF IDEAS.

We picked up an educational paper the other day, presenting a long list of distinguished men as editors. This promised well, as the field of American education is not the place where the editorial "dummy" humbug would be tolerated. Albeit the wisdom of the periodical did not seem to be of a very solid sort, though we read on, hopefully expecting to find it at every step. At length we came upon the reviews of periodicals, and thought perhaps here we should discover the sound sense promised by the import of the editorial names. We found the story-telling magazines dissected, weighed, and measured, with care and fullness. The writer was here clearly interested in his topic; but when we came to THE POPULAR SCIENCE MONTHLY it was different. The writer said he never thought much of it, and, though he had no doubt there was some truth in Evolution, he did not like to have it thrust in his face and be bored with it perpetually in accordance with the usage of this periodical. This was the first time that he had broken out into adverse criticism. He had been hitherto much pleased; the contents of the story-telling magazines had not bored him. Whereat we reflected upon the different values assigned by different minds to different orders of ideas. We think the trashy love-sick stories, the idle gossip about notorious persons, and the dashing sensational criticism, which make up the chief portion of our literary periodicals, to be not very important; and on the other hand we think that Evolution, if true, is a very important matter indeed, and as the case stands it seems to us of very great interest to know what the ablest men of the age are thinking about it. Its establishment and general acceptance

must work the deepest and most far-reaching revolution in human thought of any truth to which the human mind has ever attained. Therefore we have taken some pains to keep our readers informed about it. And this was the more necessary, as the literary periodicals of large circulation pass the subject by, and the larger the circulation the more carefully is it ignored. They value, prefer, and select that which will "pay," and in so doing they cater, for mercenary purposes, to the caprice frivolity, prejudice, and ignorance of their readers, not troubling them much with the great and serious truths which science is working out for the world. It is gratifying to find that we are not singular in our estimate of the relative moment and significance of these two forms of intellectual occupation. A writer who gives elaborate consideration to President White's "Warfare of Science" in the *Westminster Review* opens with the following pungent observations:

"It has always seemed to us a matter for some wonder that people should take such a deep interest in the peddling events of poor individual human existences, and so little in the dynasty of ideas; that they should be content to wear their eyes out over the driveling three-volumed account of the loves and hates of vapid men and women, to indulge their finest emotions over the fifth act of some puling melodrama, and yet be altogether indifferent to the gigantic drama of truth in which the unity of place is the world, the unity of time the centuries, and the actors are beneficent truths or malevolent errors. Why men should be indifferent to these momentous events in the past which constituted the history of science, the history of philosophy, and, in the truest sense, the history of religion, and yet should enter with such eager zest into the gossip of the day and the trivialities of personal reminiscence, it is difficult to say. But, however hard it may be to discover the meaning of, there is no possibility of doubting, the fact. While the personal histories of men who have very small claims upon our better sympathies are read with avidity, the impersonal narrative of truths which have paramount claims upon our hearts and our heads are treated with the passive contempt of neglect. Men are much to us, while doctrines are little. We like to have our truths in the flesh; and we are too apt, when we find a doctrine incarnated, to neglect the sacred revelation and worship the man, to transfer the reverence which is due to an idea to the individual who is, as it were, the bearer of it. Here we have, in epitome, the history of many religions. Men will worship the truth with startled reverence, then they will worship the truth-bearer and overlook the truth in the symbol, and forget that of which it is the sign."

CONCERNING "BLUE GLASS"

We are asked why we do not discourse of Pleasonton and "blue glass." Why should we? Is it not abundantly considered by the press already? The object of our pages is to treat of subjects that are too generally neglected; to give expression to those great results of discovery and scientific thought which get but a meagre share of attention from the popular press, and we cannot find half room enough to do this work as it should be done. "But, really, what do you think of Pleasonton, and the blue-glass cure?" is now the obtrusive question. Well, we think that the man is a pestilent ignoramus, and his book the ghastliest rubbish that has been printed in a hundred years. He may be entirely honest, but that is no reason why we should give attention to his egregious folly. Pleasonton, however, it must be confessed, serves one important function: he gauges for us the depth and density of American stupidity. De Morgan says, somewhere, that certain men appear occasionally to play the part of "fool-ometers" in the community, that is, to measure the number and quality of the fools furnished by any given state of society. Pleasonton has done this for us with an accuracy that leaves nothing to be desired. Our showing in this respect is on a very handsome scale, fully commensurate with the length of the Mississippi, the sweep of the prairies, the glory of the Centennial Exhibition, the grandeur of the national debt, and

the splendid proportions of our system of education. He is a public benefactor, in that he has given us another "big thing." The interesting point just now about "blue glass" is psychological. It is an exponent of popular intelligence, an index of culture, a register of common-school work, and a test of the influence of colleges. Our collective schools produce in the community a certain state of mind; "blue glass" indicates it. There is evidently a very close connection here, and the problem deserves to be worked out. If the Intercollegiate Literary Association will offer an additional prize for the best essay on the connection between the study of Latin and Greek and the "blue-glass" mania, THE POPULAR SCIENCE MONTHLY will furnish the money for the purpose.

LITERARY NOTICES.

THE ENGLISH CONSTITUTION, AND OTHER ESSAYS. By WALTER BAGEHOT, Author of "Physics and Politics," Editor of the *Economist*, etc. Pp. 468. New York: D. Appleton & Co. Price, $2.

As we sit down to write a notice of this interesting volume, we are startled by the painful intelligence of the sudden death of its distinguished author. Mr. Bagehot was in the prime of life and the full vigor of his powers, as attested by the recent fertility of his pen and the sustained character of his intellectual work. His position as a writer was quite unique in the literature of our time. Strongly attracted to the study of public affairs, and devoting himself specially in his weekly journal to the consideration of economical and commercial subjects, he always dealt with them in a broad, philosophical spirit, and wrote upon them in a style of peculiar literary excellence, for which he was quite unsurpassed among contemporary writers upon these topics. Besides his contributions to the reviews, embracing close discussions of government policy and commercial economies, and his admirable biographical sketches, Mr. Bagehot is chiefly known by his volumes on "Physics and Politics," "Lombard Street," and "The English Constitution." This is his most important work, and that by which he will be best known in the future. The book on "Lombard Street" is a special study of the money question, but the "Physics and Politics," which was reproduced in French under the happier title of "The Development of Nations," and "The English Constitution," are of a wider interest, as they treat, in a scientific spirit, of social questions and phenomena that concern alike people of all countries. Those who have read the "Physics and Politics" will find "The English Constitution" treated by the same method; the principles there developed being applied to English constitutional history and the structure of English social life. We cannot, perhaps, give a better account of this work than by quoting the preface to the new American edition:

"'The English Constitution,' by Walter Bagehot, has already attracted some attention in this country, but it is a work that deserves to be much more widely and familiarly known. Its title, however, is so little suggestive of its real character, and is so certain to repel and mislead American readers, that, in bringing out a new and cheaper edition of it, at this time, some prefatory words may be useful for the correction of erroneous impressions.

"It is well known that the term 'Constitution,' in its political sense, has very different significations in England and in this country. With us it means a written instrument, decreed at a certain time to be the supreme law of the land. Hence when a book appears upon the American Constitution, if not a history of its adoption, it will probably be a commentary upon its meanings; that is, some kind of a law-treatise, dealing with the technical interpretations of a legal instrument. The English, on the contrary, have no such written document. By the national Constitution they mean their actual social and political order—the whole body of laws, usages, and precedents, which have been inherited from former generations, and by which the practice of government is regulated. A work upon the English Constitution, therefore, brings us naturally to the direct consideration of the structure and practical working of English political institutions and social life.

"The American Constitution was framed

by a convention; the English Constitution is a growth of centuries. Books written upon the two Constitutions are, therefore, likely to differ, much as a manual of carpentry differs from a hand-book of physiology; the former belonging rather to the province of constructive art, and the latter to that of natural science. While in the study of the American Constitution we are occupied with the 'intentions of the framers,' the 'rules of construction,' and the lore of lawyers, to get at the sense of a printed tract, the study of the English Constitution introduces us more directly to facts and phenomena, or the laws of political activity, social change, and national growth. These objects of inquiry obviously lend themselves to the scientific method of treatment, which aims to trace out the working of natural causes and inherent principles, and hence has interest for all students of political philosophy. Mr. Bagehot's work is written virtually, if not formally, from this point of view; it is pervaded by the scientific spirit, without taking on the technical forms of scientific exposition.

"With the author's inclination and capacity to regard public questions in their scientific aspects, many readers are already familiar through his suggestive volume entitled 'Physics and Politics.' 'The English Constitution' is a work of the same quality, and treats its subjects very much with reference to the principles of human nature and the natural laws of human society. It is a free disquisition on English polititical experience; an acute, critical, and dispassionate discussion of English institutions, designed to show how they operate, and to point out their defects and advantages. The writer is not so much a partisan or an advocate as a cool, philosophical inquirer, with large knowledge, clear insight, independent opinions, and great freedom from the bias of what he terms that 'territorial sectarianism called patriotism.' His criticism of the faults of the English system is searching and trenchant, and his appreciation of its benefits and usefulness is cordial, discriminating, and wise. He discusses old traditions and modern innovations, aristocratic privileges and democratic tendencies, with an absence of prejudice that comes from a predominant scientific temper of mind. Taking up in succession the Cabinet, the Monarchy, the House of Lords, and the House of Commons, he considers them in what may be called their dynamical interactions, and in relation to the habits, traditions, culture, and character, of the English people. The book, indeed, is full of instructive episodes, and sagacious reflections on the springs of action in human nature, the exercise of power by individuals or political bodies, the adaptation of institutions to the qualities and circumstances of the different classes who live under them, and numerous points of political philosophy, which are applicable everywhere, and have an interest for all students of political and social affairs.

"There is much in Mr. Bagehot's volume that bears very suggestively upon the state of things in this country. His comparison, in various points, of the working of cabinet government with that of presidential government raises questions regarding our own system which are forced into greater prominence by every decade of our national experience. But the book should be read by Americans not only for the interesting information it contains, and the brilliant light it throws upon the internal polity of a great nation from which we have derived so much of our own institutions, but because it will exert a widening and liberalizing influence upon the minds of our people, who are too apt to look upon all other goverpments with a kind of bigoted contempt. Our intense politics, chiefly occupied with selfish and sordid interests, and bitter personal rivalries, tend to exclude from this sphere of thought everything like science, or the large and liberal study of political principles. Narrow views lead to a depreciation of everything foreign that differs from our own system and practice. A distinguished professor in one of our leading colleges remarked that, when the students come up in their last year to acquire some notions of political science, their want of information relating to everything beyond the limits of their own country—their ignorance of anything like comparative politics—is to the last degree discreditable. Such narrowness is only to be corrected by travel and extended observation, or by cultivating those studies and reading those books that will give clear and just conceptions of the policy of other leading nations. Mr.

Bagehot's analysis of the English Constitution will be helpful to this end; and we doubt if there is any other volume so useful to our countrymen to peruse before visiting England. It will enable Americans to understand many things that at first perplex and disgust them in an old historic country, where all that most impresses the mind is so different from what we are accustomed to here.

"It remains further to say that Mr. Bagehot's work has a charming readableness that would not be suspected from its title or subject. It is written with an easy liveliness, a vivacious wit, and a felicity of style, that place it high in the scale of literary excellence.

"The studies of character of Brougham and Peel, that are appended to the present edition, and have not before appeared in this country, will be read with avidity, as they not only serve to throw additional light upon the modern politics of England, but give us an interesting insight into the intellectual life of two of the most conspicuous men who have figured in public affairs during the past generation."

THE SYNTHETIC PHILOSOPHY.

THE PRINCIPLES OF SOCIOLOGY. By HERBERT SPENCER, Author of "First Principles of Biology," "Principles of Psychology," etc., etc. Vol. I., pp. 734. New York: D. Appleton & Co. Price, $2.50.

THE sixth volume of Spencer's "Synthetic Philosophy" is now before us. This great work was entered upon with many doubts as to its merits if executed, and many more as to whether it would ever get done at all. It has, however, moved slowly forward for the last fifteen years, against obstacles, both internal and external, which would have ordinarily brought such an enterprise to a stand long ago. The author's imperfect health has been a serious and constant impediment; the expensiveness of the undertaking has greatly imperiled its continuance; and the carelessness, stupidity, and downright perversity of reviewers, or those who undertook to interpret the system to the public, have been little calculated to inspirit the author in the progress of his work. Instead of welcoming with sympathy and intelligent encouragement a great effort like this to effect a higher unity of the different departments of knowledge, which modern science has begun to make possible, Mr. Spencer has been treated rather as if he had committed some grave offense against the interests of mankind. We have still large classes who look upon science with jealousy, and especially resent any effort to make it the basis of philosophy, or to develop it into a comprehensive and authoritative body of thought; and these classes have opposed and vilified from the commencement Spencer's work without scruple or reserve. It is gratifying to note that this unworthy feeling is giving way in many quarters, and is replaced by a growing disposition to do justice to his views; but in other quarters the old tactics of depreciation and misrepresentation are still pursued. We refer to the latest example. Our readers will remember that a year or two since the *British Quarterly Review* opened its columns to a very unmanly and vindictive assault upon Spencer, which had no excuse even under the largest license of decent reviewing. That there was some animus in the writer's mind quite apart from the fair and legitimate purpose of such work, was obvious enough at the time; but, if there could have been any doubt about it, that doubt is dispelled by the recent course of this *Quarterly*. In its January issue it contained another elaborate article professing to be a review of Spencer's "Sociology;" but the reader will hardly credit the statement that this work was not even referred to in the article. It was nothing less than an attack upon the old "Social Statics," a book published twenty-six years ago, and having in its preface to the later reprints an explicit warning to all readers that it does not contain a true representation of Mr. Spencer's present views. The course of the *Quarterly* was all the more outrageous, when it is remembered that Mr. Spencer had stated in this preface that the subject discussed in "Social Statics" would be reconsidered and placed upon a broader basis in the "System of Philosophy" upon which he has been at work since 1860. The writer in the *Review* added, in a note at the end of his article, that at the time it went to press the volume of Spencer's "Principles of Sociology" was

not yet published—a false statement, as it had been issued in quarterly parts during the past two years by Williams & Norgate, of London, the publishers of "Social Statics" and all the volumes of the "Philosophy." Though we may not expect in *British Quarterly Reviewers* any very high sense of honor, there is a barefaced recklessness in this proceeding which well illustrates the sort of treatment that Herbert Spencer has been receiving ever since he published the first volume of his "Philosophy" in 1862.

The readers of THE POPULAR SCIENCE MONTHLY will hardly need to be told that the volume now published is the first of three which are intended to work out systematically the principles of the science of society. We have often explained the relation of these works to the philosophical volumes that have preceded them, and to the "Descriptive Sociology," which gives a comprehensive account of different types of the social state; and we have published various articles, from advance-sheets of the work itself, illustrating the quality and scope of the discussion contained in the volume before us. The work differs widely and profoundly from any that has ever appeared professing to deal with the subject of social science, and it is gratifying to see at last some cordial recognition of its great originality, value, and importance, from the leading critics of the English press. This is all the more satisfactory, that Mr. Spencer has conquered it against the steady pressure of a powerful and long-sustained antagonism. Having commented freely upon the work, and given illustrations of it, in the course of its publication, we prefer now to furnish our readers with the view taken of the completed volume by an influential London journal. The following is the notice that appeared in the *Pall Mall Gazette*:

"Those who have followed the development of Mr. Spencer's 'System' will have no difficulty in understanding the position held in it by the present volume. Hitherto he has been occupied in setting forth the laws of organic evolution, the 'Principles of Biology' having dealt with the physical aspect of that process, the 'Principles of Psychology' with its mental aspects. Both these works treat of the individual life of the organism; but when organisms come into relation to each other, form societies, and produce results which could not be achieved except by coördinated action, we are confronted by a new set of phenomena. We are in presence of what Mr. Spencer calls super-organic evolution. The task of sociology—it is now, we fear, too late to protest against the use of one of the most disagreeable words ever coined—is to interpret these new facts, to classify them, and to render intelligible the passage from one stage of progress to another. Among bees, wasps, and ants, we find the first indications of coöperation, associated with a certain degree of division of labor; and some of the higher types of vertebrata, such as rooks, combine in a still more marked manner. These instances of coördinated action are, however, of slight moment compared with the phenomena presented by human societies; it is, therefore, with the latter alone that sociology is concerned.

"The subject is so vast and complicated that it is difficult to treat of it without being either dull or superficial. Mr. Spencer, as those who know his writings would expect, escapes both dangers. As in his previous expositions, he confines himself to a few large principles; and these are so clearly expressed, so systematically arranged, and supported by so immense an array of proofs and illustrations, that readers wholly unaccustomed to philosophical inquiry may follow his argument with interest. Not even a German professor could have undertaken to bring together without help the enormous mass of materials which are here utilized. Mr. Spencer has had excellent assistance in collecting facts, and he has woven them with the skill of a master into a consistent and suggestive theory.

"In social evolution there are two factors: extrinsic and intrinsic. The former include all those outward influences, such as climate, surface, flora, and fauna, which determine human action; by the latter are meant the qualities of the units that make up society. Mr. Spencer devotes only one chapter to the extrinsic factors; but this suffices to indicate how many favorable conditions are necessary to the formation of a society, and how rarely these condi-

tions occur. As regards the internal factors, it clearly would not be enough to present the peculiarities of the civilized man, who inherits acquired tendencies and is to a large extent moulded by the society into which he is born; we must go back to the time at which physical forces were not controlled by intelligence, and when men lived together only in loosely-formed groups. All the world knows how Rousseau represented to himself the primitive man, and there are still, perhaps, people who affect to talk enthusiastically of the 'noble savage.' If we compare this sentimental conception with the picture drawn by Mr. Spencer, we are furnished with a tolerably accurate measure of the advance which has been made in the methods of investigating such subjects. The philosopher of to-day is not less fond of theory than his predecessor of the eighteenth century, but in his hands theory is never divorced from fact; it is incessantly brought to the test of reality, and in reality finds its only true starting-point. Hence, while Rousseau's idea could give rise only to a great many futile regrets and aspirations, Mr. Spencer's is the basis of a thoroughly scientific description of the long course through which mankind have passed from the simplest to the most complex forms of life. The primitive man is regarded in three different aspects: physical, emotional, intellectual. He is shown to have been, on the average, smaller than men now are, with limbs inferior both in size and structure, and a larger alimentary system, 'adapted to a very irregular supply of food, mostly inferior in quality, dirty, and uncooked.' Arriving early at maturity, he disliked change, and constitutional callousness made him insensible of evils which at a later stage become intolerable. The emotional characteristics of the savage are a 'wavering and inconstant disposition,' leading to an 'explosive, chaotic, incalculable behavior, which makes combined action very difficult,' extreme improvidence, selfishness modified only by a desire of admiration and by 'such fellow-feeling as results from that instinctive love of the helpless which he possesses in common with the inferior animals.' Intellectually the uncivilized man is on a level with the children of civilized parents. The perceptive faculties are keen, the reflective scarcely at all developed; like children, he has a strong mimetic tendency; he cannot concentrate attention on anything higher than simple facts; he has few general ideas, and being without any conception of natural order, he is incapable of rational curiosity or surprise. The question is sometimes asked, 'Why, if the human species has been so long in existence as the doctrine of evolution implies, did so many ages elapse before civilization arose?' No one who attentively considers these characteristics of the savage, and takes into account the outward difficulties with which he has to contend, will be surprised that man so long remained a slave to circumstances. The astonishing thing is, that any primitive tribes ever lighted upon the happy combination of conditions which enabled them to grow into progressive communities.

"In order to understand the institutions of civilized and semi-civilized societies, we must not satisfy ourselves with a general description of the faculties of the primitive man—we must investigate the ideas suggested to him by his experience. The chapters devoted to these are by far the most original and valuable in the present volume. It is common to judge savage conceptions by a reference to our more advanced knowledge, in the light of which they, of course, excite only surprise or amusement. Mr. Spencer, guided by the statements and hints of travelers, puts himself as much as possible in the position of primitive men, and looks at the world with their eyes; and the consequence is, that he succeeds in proving almost that their ideas were not only natural, but the sole ideas to which the evidence within their reach could have conducted them. One of the earliest of their theories is that of a second self. This arises, in the first instance, from dreams, the experiences of which the savage regards as real. He has no notion corresponding to that of mind; hence, when he dreams that he has been hunting or engaged in deadly conflict with an enemy, he never doubts on awaking that the incidents actually took place. Others testify that he has not moved; but this only shows that there must be a double which is capable of going away and having adventures of its own. He is untroubled by incongruities

that would perplex a more developed intelligence, for the facts seem to him beyond question, and he is familiar with many changes in Nature—the appearance and disappearance of clouds, the blowing of the wind, the waxing and waning of the moon—not at all less mysterious. His idea is confirmed by occasional instances of somnambulism; and the phenomena of swoon, apoplexy, and other forms of insensibility, are most readily explained by assuming that the body has been temporarily deserted by its ghost. In death the other self, which is upbraided before its departure by the friends of the dying man, says farewell; but it continues to exist, sometimes in its old haunts, sometimes in the neighboring woods, sometimes in the country whence the tribe originally came. It may even return to the body, and with a view to this contingency the latter is often carefully protected, and in many instances there are elaborate processes for arresting decay; if revival is dreaded, an exactly opposite course is pursued. In the earliest stages of development the ghost is a copy of the body, and may, like it, die; but tribes a little more advanced attenuate its substance until at length it is completely etherealized. It then has an enduring existence, and side by side with the world of the living is the more populous world of the dead. Ghosts continue to act as ordinary men, and are provided with food, weapons, canoes, horses, dogs. They are the cause of every unusual occurrence, and, entering bodies which they find temporarily vacant, occasion epilepsy and convulsions, delirium and insanity, disease and death. Every involuntary act, like sneezing or yawning, is due to them; and the necessity of controlling them gives rise to the class of exorcists and sorcerers. If friendly, they inspire the possessed, whose words are accepted as a revelation of higher wisdom. They are, of course, regarded with intense awe, and worship of them is, according to Mr. Spencer, the first manifestation of the religious sentiment. He goes much further than this, and finds in ancestor-worship the origin of all worship whatever. Idols are simply rude images of the dead, which ghosts are in some mysterious way believed to inhabit; hence food is given to them, and the family respectfully waits—that is, fasts—until they have eaten internally. A fetich is any object in which a ghost is supposed to dwell; and no object strikes the senses in a strange manner without having its peculiarity attributed to ghostly presence. This view of the fetich is not in accordance with current ideas; but it is confirmed by the fact that in cases in which the ghost-theory has not been evolved there is no fetich-worship, whereas the latter abounds where the former exists. But animals, plants, natural objects and forces, are also worshiped: how can these be in any way connected with ancestor-worship? Mr. Spencer applies his principle with unfaltering confidence even to these phenomena. Serpent-worship is the most general of all forms of animal-worship; it originates in the haunting of houses by certain kinds of snakes believed to be possessed by the ghosts of departed ancestors, who thus enter their old homes. In India the cobra is a common intruder in houses, and it is everywhere sculptured as a god; the Egyptian asp affords an instance equally remarkable. Bats and owls, which haunt caves and other burying-places, are also taken for metamorphosed ancestors. Some striking peculiarity will often secure for a man the name of an animal whose character his resembles. Unaccountable as it seems to us, the savage who hears his ancestor talked of as 'The Tiger' concludes that he is descended from one of those creatures; so that the tiger naturally becomes an object of reverence. The like is true of all animals, insignificant and strong alike, the names of which are applied to savages either in ridicule or respect by their neighbors. In this misapprehension of the meaning of words Mr. Spencer likewise finds the chief explanation of Nature-worship and plant-worship. A man is called Cotton or Tobacco, the Dawn, the Sea, the Moon, or the Sun. His descendants, taking the word literally, do not hesitate to regard the natural power or plant, whichever it may be, as their ancestor, and present it with the usual offerings. To civilized men this seems almost incredible; but it must be remembered that to the savage nothing seems impossible, because he has not attained to the idea of regular sequence in the world. And his language is so imper-

fect that he has no means of distinguishing after a certain interval between the literal and metaphorical application of words. With respect to anthropomorphic deities, Mr. Spencer argues that they are ancestors whose qualities are idealized and expanded.

"Ancestor-worship has never before been turned to such advantage in the interpretation of so many facts; and the ease with which the theory works gives it a certain charm. We see no reason, however, why Mr. Spencer should exclude every other cause in the production of early mythologies. The influences he has defined may all act as he describes; but they do not necessarily exhaust the sources of the religion of savages. He is as nearly angry as it is possible for so calm a thinker to be with 'the mythologists,' who represent uncivilized man as mistaking the names given to the forces and objects of Nature for the names of living beings. But surely this is not more strange than the process he himself has expounded, since in both cases the savage ends by finding in the outward world qualities which exist only in his own imagination. If he is unreasoning enough to suppose that the sun is his ancestor because his grandfather was so called, we need feel no surprise at his regarding the sun as alive merely on account of the effects it daily produces; and so of the moon, the dawn, or the wind. Mr. Spencer will not admit that the savage has any tendency to ascribe life to what is inanimate; but children constantly do so, and he insists that children and savages have a strong intellectual resemblance. We are not arguing for the theory which has been so persistently, if not always judiciously, advocated by Mr. Max Müller and Mr. Cox; we only say that within certain limits it may also be true. Religious phenomena are so complicated that it is improbable we shall be able to explain them by the modifications of any single principle.

"In several very interesting chapters Mr. Spencer uses the analogy between societies and organic bodies to illustrate the truth that 'social evolution forms a part of evolution at large.' He then passes to the domestic relations, in connection with which he discusses the many different forms of marriage and of marriage-ceremonies. To persons who believe that man has an intuitive perception of right and wrong in the relations of the sexes there could be no more suggestive study than that of exogamy and endogamy, promiscuity, polyandry, polygyny, and monogamy. Mr. Spencer does not so much argue against the intuitive theory as oppose to it the process by which, as a matter of fact, our present moral conceptions have been produced. This is, indeed, the characteristic of the whole work. Its method is throughout constructive; but for that reason it is much more effective in destroying popular doctrines regarding the origin and growth of many vital ideas than any amount of merely negative argument."

ELECTRICITY AND THE ELECTRIC TELEGRAPH. By GEORGE B. PRESCOTT. 564 Illustrations. New York: D. Appleton & Co. Pp. 978. Price, $5.

IN this elaborate volume we have the detailed story of the telegraph, in a form suitable both for the instruction of general readers and for the guidance of those practically engaged in the art. The illustrations are copious and well executed, and all the curious complications of telegraphic mechanism, and the mysterious ways of electricity that are made available to the great end of the rapid transmission of intelligence, are described clearly and fully by the author. Mr. Prescott has been at great pains to bring forward the valuable contributions of foreign nations, especially the Germans, who have done more in telegraphy than they have had credit for, and his work may be commended for its comprehensiveness as well as that thoroughness of treatment which is indispensable to a first-class manual upon the subject.

LESSONS IN ELECTRICITY. At the Royal Institution. By JOHN TYNDALL, F.R.S. New York: D. Appleton & Co. Pp. 113. Price, $1.

FOR entering into physics through the experimental gateway, and by the use of simple apparatus, electricity has special advantages. Its experiments are simple, the effects distinct and striking, and the theoretical pathway to principles not difficult to follow, and well suited to exercise the reasoning powers. Dr. Tyndall has there-

fore done a most valuable service to science-teaching by preparing this little manual, which is admirably fitted to lay the foundation of an actual and thorough knowledge of the science. His experiments are ingeniously simple, and at the same time telling—each one carrying the pupil along a step further in his progress. The text is clear, pointed, compressed, and attractive, as Prof. Tyndall knows so well how to make it. But it is almost superfluous to call the attention of our readers to the excellences of this little work, as several portions of the earlier English edition have been already published in the pages of this MONTHLY.

PHILOSOPHICAL DISCUSSIONS. By CHAUNCEY WRIGHT. With a Biographical Sketch of the Author by CHARLES ELIOT NORTON. New York: Henry Holt & Co. Pp. 434. Price, $3.50.

THIS volume opens with a very pleasant and appreciative sketch of Mr. Wright by his friend Charles Eliot Norton, from which we gather that he was a gentleman of admirable personal traits which strongly attracted all who knew him. The book is made up of his literary remains, consisting of nearly a score of articles, contributed chiefly to the pages of the *North American Review* and to the *Nation* for the last fifteen years. They evince the strength of an able and independent thinker; but the style in which they are written is somewhat heavy. They are predominantly critical and controversial, as the author does not seem to have arrived at any constructive or systematic views of his own. He highly appreciated Mr. Darwin, and championed him against the criticisms of Prof. St. George Mivart, doing the work so well that it was thought important to republish it in London. There are many things in the articles of Mr. Wright that are well worth preserving, and his friends could in no way have better honored his memory than by collecting and publishing them in the elegant and substantial form which Mr. Holt has given to the volume. It should be mentioned that two of the papers, a fragment on "Cause and Effect," and the beginning of the article on Lewes's "Problems of Life and Mind," are published in this collection for the first time.

RUSSIA. By D. MACKENZIE WALLACE, M. A. New York: Henry Holt & Co. Pp. 620. Price, $4.

As the eyes of observers of international affairs are now turned upon Russia, there will be an increasing interest in all that relates to the domestic and social structure of that powerful empire. It is very rare that, at such a crisis of curiosity, there appears a work so eminently suited to satisfy it as in the present issue of Mr. Wallace's volume. It is a book that would make a mark and a sensation at any time, but the circumstances will now make it "the book of the season." Its author for the past six years has occupied himself with studying the people, the resources, and the institutions of Russia by personal observation and careful inquiry, residing in various cities and villages in different parts of the country, most favorable to varied and enlarged familiarity with the facts of which he was in pursuit. Mr. Wallace's book is written in good style, with no ambition for mere effect, but in the direct, common-sense way of a writer who has much to say, and goes directly to the point. His descriptions are graphic, without being wearisome, and the treatment of his special topics, though often full, occupies the reader closely to the end. It is full of important information, much of which is fresh and novel, in regard to the condition of the country, its peasant-life, the village communities, the larger towns and mercantile classes, imperial administration and local self-government, land proprietorship, the nobility, education, religion, church and state, military characteristics, emancipation of the serfs, the law-courts, the railroad system, social classes, industrial resources, the features of the country, and lastly, in the thirty-fourth chapter, the Eastern question, and the problem of territorial expansion. All these important subjects Mr. Wallace has handled with skill, and with constant reference to the great liberalizing tendencies of the age which are displayed in Russia as well as other leading countries, and under remarkable and peculiar conditions. Prefixed to the volume are two colored maps of Russia, one showing the density and distribution of the population, the railway system, and the grade of cities in respect to the number of their inhabitants; the other ex-

hibiting the distribution of the principal agricultural products. Any one who will familiarize himself a little with these maps, and then deliberately read the book, will probably get a great deal more knowledge than he could obtain by months of travel in the Russian Empire.

REPORT OF THE COMMISSIONERS OF AGRICULTURE FOR THE YEAR 1875. Pp. 536. Washington: Government Printing-Office.

OUR readers are not altogether unfamiliar with the matter contained in this "Report," for we have from time to time during the past year made selections from the monthly reports, especially of observations and experiments made by Mr. Glover and Mr. McMurtrie, respectively the botanist and the chemist of the department. These are repeated in the annual report, or, rather, they are bound up with it. The volume also contains papers on the forest-trees of the United States, varieties of fruits, alfalfa, the French mode of curing forage, hog-cholera, and several other subjects of interest to the agriculturist.

PROPERTIES OF CONTINUOUS BRIDGES. By C. BENDER, C. E. Pp. 150. Also, BOILER-INCRUSTATION. By F. J. ROWAN. Pp. 88. New York: Van Nostrand. Price, 50 cents each.

THE series of handy volumes on applied science to which these two treatises belong needs no commendation from us. The works are of a severely practical nature, and their merits are well understood by the engineers and mechanicians to whom they are addressed.

EFFECTS OF ALCOHOLIC POISON. By J. H. KELLOGG, M. D. Battle Creek, Michigan: *Health Reformer* print. Pp. 124. Price, 25 cents.

DR. KELLOGG attempts in this little pamphlet to discuss the question of alcohol in "its physical, moral, and social effects," and yet he finds room for a long chapter of twenty-seven pages on "Wine and the Bible," in which he wrestles manfully with such contradictory texts as those which call wine "cruel venom of asps," and those which say that "it maketh the heart glad."

THE JUKES: A Study in Crime, Pauperism, Disease, and Heredity. Also, Further Studies of Criminals. By R. L. DUGDALE, Member of the Executive Committee of the Prison Association, New York. With an Introduction by ELISHA HARRIS, M. D., Corresponding Secretary Prison Association. New York: G. P. Putnam's Sons.

THE title-page is itself a history of this remarkable work. To the student of the social sciences this pamphlet is a valuable contribution, giving as it does in tabulated details the lives of a family of large numbers, whose condition had become so fixedly criminal that harlotry, bastardy, and a career of law-breaking, ever gravitating prisonward, had become the inevitable heirship of the "Jukes," the word itself becoming a synonym of evil.

EARLY MIGRATIONS.—ORIGIN OF THE CHINESE RACE. Philosophy of their Early Development, with an Inquiry into the Evidences of their American Origin; suggesting the Great Antiquity of Races on the American Continent.

JAPANESE WRECKS, stranded and picked up adrift in the North Pacific Ocean, ethnologically considered.

EARLY MARITIME INTERCOURSE OF ANCIENT WESTERN NATIONS, chronologically arranged and ethnologically considered.

THE above are from the "Proceedings of the California Academy of Sciences," 1876; each has the common heading, "Early Migrations," and their author is Charles Wolcott Brooks. The pamphlets give evidence of large research, and are at least ingenious. The drift is toward the settlement of China from the American Continent, probably Peru. Is not the following statement made carelessly? "North American Indians have never been cannibals" ("Origin of the Chinese Race," p. 27). Do not the discoveries of the late Prof. Wyman, in the shell-heaps of Florida, speak to the contrary?

ADDRESS BEFORE THE ST. LOUIS ACADEMY OF SCIENCE, at its Annual Meeting for 1877, by the President, CHARLES V. RILEY. St. Louis, Mo.: R. P. Studley & Co.

AN interesting *résumé* of the year, in matters pertaining to the biological sciences, with, perhaps, a special attention to home work.

A PRACTICAL TREATISE ON DISEASES OF THE SKIN. By LOUIS A. DUHRING, M. D., Professor of Diseases of the Skin in the Hospital of the University of Pennsylvania; Physician to the Dispensary for Skin-Diseases, Philadelphia; Author of Atlas of Skin-Diseases, etc. Philadelphia: J. B. Lippincott & Co. Pp. 600. Price, $6.

As a manual of dermatology for the medical practitioner this treatise will be found valuable and satisfactory. It is practical, thorough, and systematic, without claiming to be exhaustive, in the erudition of the subject, or the details of its historical literature. It presents the elements of the subject concisely, giving all the important facts in connection with each disease treated of. In classification Dr. Duhring follows the authority of the celebrated Prof. Hebra, of the University of Vienna, his former teacher, and to whom the present work is dedicated. A special and highly-commendable feature of Dr. Duhring's work is the definition of the various skin-diseases, which he has made out from the standpoint of clinical observation with a view to its practical usefulness, and which consists mainly of succinct descriptions of characteristic lesions and symptoms, where the cases were not too complex and obscure to make clear definition possible. In the sections devoted to treatment, while the author makes due reference to all those methods that are favorably regarded by the profession, he has also brought distinctly forward those remedies and modes of treatment that he has found of greatest benefit in his own medical experience.

Skin-diseases appear to undergo grave modifications in different geographical circumstances, so that well-executed treatises upon the subject in one country are liable to lose their accuracy when applied to other countries. On this point Dr. Duhring remarks: "I can but incidentally refer to the fact that disorders of the skin manifest more or less variation in type as they occur in one or in another part of the world. Having had some few years ago favorable opportunities for observing a large number of cutaneous affections in the various countries of Europe, and since then of studying these diseases in the United States, I can state that in many instances they differ materially in type as they are seen on the two continents. Without entering into this interesting subject, it may be remarked that the diseases met with here resemble more closely those of Great Britain than those of either France or Germany. A recognition of this fact must, I think, go far in accounting for the discrepancies which exist in the descriptions of certain diseases as given by trustworthy observers."

ANCIENT PAGAN AND MODERN CHRISTIAN SYMBOLISM. By THOMAS INMAN, M. D. Pp. 174. With numerous Illustrations. New York: Bouton. Price, $3.

THE exceedingly curious figures which abound in this volume give to it nearly all the value which it possesses. The book contains no less than 180 woodcut figures, together with 19 lithograph plates of full-page size. With hardly a single exception, they are more or less plainly symbolical of sexuality in religion. The author has undoubtedly rendered a great service to students of that particular aspect of the religious idea, by bringing together so many interesting memorials of the wide diffusion of sex-worship. His own remarks and speculations, however, do not carry much weight.

WE reproduce some of the things said by the London *Examiner* in reference to Arnott's "Physics," which, in its new form, is attracting much attention:

"It was in 1827 that Dr. Arnott took the world by storm. The publication, in that year, of the first volume of the 'Elements of Physics' was probably the greatest 'sensation' ever made by a scientific work, purely as an exposition. The first edition was sold in a few days; a second had to be followed by a third, a fourth, and a fifth, in as many years. If the author had devoted himself to keeping it up by the necessary improvements, it would have long continued to distance all competition in its own walk. It had an equal run in America, and was translated into nearly all the Continental languages. The popularity of the book was not due to any meretricious qualities. There was an extraordinary profusion of interesting examples, but these interfered less than in almost any other popular work with the understanding of the doctrines—

in fact, were, as they ought to be, aids to the proper end of the teacher. The best proof of this was the number of individual minds that were stimulated to a scientific or intellectual career by the study of the work. The hearty testimony borne by Herschel and Whewell to the merits of the 'Physics,' scientific as well as expository, was incompatible with any infusion of claptrap.

"It would be easy to set forth the art, or rather the genius, of Arnott, in the composition of his book. He had great literary power, in the mere command of expression, and in the composition of his sentences, which are both lucid and flowing. Many scientific writers have had this much. But he had also a thorough and unfaltering perception of the intellectual capabilities of an average reader, and never for a moment presumed too much upon these. He labored, with no small success, to bring the doctrines of natural philosophy down to a level of mind that had never before been permeated by them; and, if any part of the subject was hopelessly intractable, he passed it by.

"Besides his amassed store of popular illustrations, stated in easy language, the work had the further charm of a species of sentiment or eloquence, often enough attempted in connection with science, but not often so well kept up. The author fully complied with Plato's condition of philosophical teaching—to exhibit the goodness of the divine plan of the Cosmos. His eloquent passages on this subject, together with his choicest illustrations of physical laws, were largely adopted into the common-school reading-books.

"The new editors have shown themselves aware of the backward state of the exposition in many parts, and have freely employed the power of excision and substitution. We should say, from a rough estimate, that a full half of the work is new. In the branches of Acoustics, Heat, Light, and Electricity, many additions were obviously necessary. In Mechanics, there has been more permanence, and Arnott's exposition is less interfered with; but it was essential to supplement his chapter on Motion and Force with a view of the doctrine of conservation of energy, which the author would have been delighted to handle in his own peculiar way, but scarcely touched upon even in his latest edition. However the work of revision may have been distributed among the three editors, they have been successful in bringing up the subjects to the most recent views, and in illustrating them by well-chosen examples and diagrams. The work is one likely to keep its place among treatises on a similar scale. Extending to nearly 900 pages, it comprises a tolerably full body of information in all the branches, while the reader has still the benefit of the expository genius and eloquence that charmed and astonished the world forty years ago, and has not yet been superseded."

PUBLICATIONS RECEIVED.

Proceedings of the Thirty-second Annual Meeting of the New York State Teachers' Association. 1876. *School Bulletin*, Syracuse, N. Y. Pp. 119.

On the Atmosphere of the Sun and Planets. By David Trowbridge, A. M. 1876. Pp. 7.

The Relations of Medicine to Modern Unbelief. By Richard O. Cowling, A. M., M. D. Louisville: John P. Morton & Co. print. 1876. Pp. 11.

Report of the Committee on Naval Affairs to the House of Representatives on a Bill to authorize and equip an Expedition to the Arctic Seas. Pp. 13.

Proceedings of the American Chemical Society. Vol. I., No. 2. J. F. Trow & Sons print. 1876. Pp. 49.

The *Western Review of Science and Industry*. Edited by Theodore S. Case. February, 1877. Vol. I., No. 1. Kansas City, Mo. Subscription, $2.50 per annum.

Milk-Sickness. By W. H. Philips, M. D. Pp. 21.

Twenty-sixth Annual Report of the Managers of the House of Refuge, made to the Governor of Maryland. Baltimore: Innes & Co. print. 1877. Pp. 28.

Check-List of the Fresh-Water Fishes of North America. By David S. Jordan, M. S., M. D., and Herbert E. Copeland, M. S. Pp. 31.

Rate of Set of Metals subjected to Strain. By Prof. Robert H. Thurston. Pp. 10.

Am I my Brother's Keeper? Discourse before the American Public Health Association, at the Annual Meeting in Baltimore, November 11, 1875. By Lewis H. Steiner, M. D. Cambridge: Riverside Press print. Pp. 11.

Kindergarten Messenger. Published by Elizabeth P. Peabody. Cambridge, 1877. Vol. I., Nos. 1 and 2. Pp. 32. Subscription, $1 a year.

Proceedings of the Boston Society of Natural History. Vol. XVIII., Part IV., April–July, 1876. Boston. Pp. 103.

Seventh Annual Report of the Commissioners of Fisheries of the State of New Jersey. Trenton: J. L. Murphy print. Pp. 42.

Geographical Surveys of the United States. Remarks on Prof. J. D. Whitney's Article in the *North American Review*, July, 1875. By Gouverneur K. Warren. Washington: Judd & Detweiler print. 1877. Pp. 28.

Local Deflections of the Plumb-Line near the Forty-ninth Parallel. By Lieutenant F. V. Greene. 1876. Pp. 13, with Diagram.

Geological Survey of Alabama, for 1876. By Eugene A. Smith, Ph. D., State Geologist. Montgomery. Pp. 100.

The Mechanical Engineer. An Address to the Graduating Class of the Stevens Institute of Technology. By R. H. Thurston, A. M., C. E. New York: D. Van Nostrand. 1875. Pp. 24.

Notes on the Ancient Glaciers of New Zealand. With Map. By I. C. Russell. 1876. Pp. 12.

Bulletin of the American Geographical Society, No. 3. Containing Annual Address of Chief-Justice Daly, delivered January 16, 1877. Pp. 70.

Science Lectures at South Kensington: Technical Chemistry. By Prof. Roscoe. London: Macmillan & Co. 1877. Pp. 46. Price, sixpence.

Dynamics, or Theoretical Mechanics. By J. T. Bottomley, M. A., F. R. S. E. New York: G. P. Putnam's Sons. Pp. 142. Price, 75 cts.

Myelitis of the Anterior Horns, or Spinal Paralysis of the Adult and Child. By E. C. Seguin, M. D. New York: G. P. Putnam's Sons. 1877. Pp. 120. Price, $1.50.

Essays on Political Economy. By Frederick Bastiat. English Translation, revised, with Notes, by David A. Wells. New York: G. P. Putnam's Sons. 1877. Pp. 291. Price, $1.25.

The Cradle of Christ: A Study of Primitive Christianity. By O. B. Frothingham. New York: G. P. Putnam's Sons. 1877. Pp. 233. Price, $1.75.

The Best Reading. Edited by Frederick B. Perkins. New York: G. P. Putnam's Sons. 1877. Pp. 348. Price, $1.25-$1.75

The Chemist's Manual; A Practical Treatise on Chemistry. By Henry A. Mott, Jr., E. M., Ph. D. New York: D. Van Nostrand. 1877. Pp. 625. Price, $6.

Washington Astronomical and Meteorological Observations, made during the Year 1874, at the United States Naval Observatory. Washington: Government Printing-Office. 1877.

POPULAR MISCELLANY.

Cotton-Culture in Egypt.—While the Khedive is taxing to the utmost the resources of his dominions in his desire to subjugate his southern neighbors, he must regard as little less than providential the reputed discovery of a new and extraordinarily-productive species of cotton-plant, the general cultivation of which in the cotton-fields of Egypt will, it is said, more than double the present annual product. According to a correspondent of the London *Times*, in the autumn of 1873, a Copt living in the upper part of the Delta, at a place called Berket-el-Sab, a station of the Cairo Railway, in the province of Menuf, noticed a plant in a cotton-field wholly different from the rest. He collected the pods, separated the seed, and planted it in secret in an isolated plot of ground. For three years he has carried on the cultivation, and now there are said to be from 800 to 1,000 pounds in the country, and the seed is sold in the public market. This seed is sold at a price twenty-five or thirty times higher than the common kind.

Comparing the product of this plant with that of the old, the *Times* correspondent remarks:

"An *ardeb* (270 pounds) of ordinary cotton-seed sows on an average eight *feddans* (acres), and produces four *cantars* (100 pounds) of cotton in seed—that is to say, the cotton with the seed inside it as it comes out of the cotton-pod. Taking this yield as the average, every ardeb planted produces 32 cantars of ginned cotton, and about 24 ardebs of seed. An ardeb of seed of the new species sows, like the other, eight feddans; but its yield is more than treble, and has even been stated at fivefold. But my most trustworthy informant only gives ten cantars per feddan, which I may add is the amount taken by one of the leading firms as the basis of their calculations as to the effect of the new plant. They add that it is difficult to say exactly what would be the ordinary yield, as all returns hitherto are the result of exceptional culture on a small scale. On this calculation of ten cantars, each ardeb of seed would produce 80 cantars of cotton in seed—that is to say, over double the amount produced by ordinary seed. At present prices each ardeb would return about £240 in seed and cotton together, instead of £96 as it does now. The new cotton, I am assured on the best authority, is of good appearance, commercially speaking, and quite equal in quality to the ordinary Egyptian cotton. The plant grows in a different manner from the ordinary cotton-plant. It grows to about the height of ten feet, has a straight, vertical stem, without branches, with very few leaves, and is thickly studded with pods. Seventy are said to have been gathered from the first plant discovered. The ordinary cotton is found on a shrub some four to five feet high, with spreading branches. Nearly a yard must be left for air, light, and growing-room between each shrub, whereas the new plant, from the absence of branches, requires only half the space."

Testimonials to Mr. Darwin.—On the occasion of his sixty-ninth birthday, Mr. Darwin was the recipient of two highly-gratifying testimonials of esteem from scientific men in Germany and in the Netherlands. From Germany came an album containing the photographs of 154 scientific men; it was inscribed, "Dem Reformator der Naturgeschichte" (To the Reformer of Natural History). The offering of the Dutch *savants* also consisted of an album, with photographs of 217 of his admirers in the Netherlands. Accompanying the latter

testimonial was a letter in which were set forth in pretty full detail the labors of Dutch naturalists before Darwin's time and since in propagating views akin to those known as "Darwinian." The first name mentioned in the letter is that of Dr. J. E. Doornik, who in 1816 went out to Java, and spent the remainder of his life in India. In his published works he held that the various modifications in which life was revealed in consecutive times originated from one another. Doornik had no influence on the thought of his time, however, and his theories were forgotten. In 1849 was published a Dutch translation of the "Vestiges of the Natural History of Creation." This work was coldly received by the representatives of natural science in the Netherlands, but found favor with the general public, and reached a third edition. Of the few Dutch scientific men who early recognized the importance of the theory of development two are named—F. C. Donders and P. Harting. The former in 1848 expressed the opinion that in the gradual change of form consequent upon change of circumstances may lie the cause of differences which we are wont to designate as species; and the latter in 1856 expressed similar views.

While visiting Utrecht in 1858, Sir Charles Lyell called the attention of the professors of the university to a paper by Wallace, in the *Journal of the Linnæan Society*, and announced as forthcoming a work by Darwin ("The Origin of Species") which could not fail to make some noise. Harting soon after declared himself a partisan of the development hypothesis, and in this he was followed by another professor in the same university (Utrecht), Miguel, Professor of Botany. In the mean time "The Origin of Species" had been translated into Dutch by F. C. Winkler. The Darwinian views were now enthusiastically adopted in the Netherlands, especially by the younger scientific men, under the lead of Emil Selenka, then Professor of Zoölogy at Leyden. Gröningen and Amsterdam were not tardy in following the lead of Utrecht and Leyden; in short, the Darwinian theory of development was very generally accepted throughout the Netherlands, and Dutch translations were published of "The Descent of Man" and "The Expression of the Emotions in Man and Animals," both by Dr. Hartogh Heys van Zouteveen. In his reply to this letter, Mr. Darwin expresses his "obligation for the very interesting history contained in it of the progress of opinion in the Netherlands with respect to evolution, the whole of which is quite new to me."

Ignorant Enterprise.—The black-slate beds of Pennsylvania have again and again lured sanguine coal-hunters to loss of time, labor, and money. In that State it is the black slate that plays the "will-o'-the-wisp" to the eager searcher after hidden wealth; elsewhere it is iron pyrites being mistaken for gold, or quartz for diamonds; and where natural deposits of wealth are out of the question, men dig into the ground in search of treasure supposed to have been buried by famous buccaneers or noted misers. Prof. Persifer Frazer lately told, at a meeting of the Academy of Natural Sciences, Philadelphia, the story of one of these searchers for mineral wealth. A farmer of Franklin County, Pennsylvania, had a dream, in which he became aware of the existence of a "treasure" in a certain field. On repairing to the spot he began to dig, and "at the first stroke of the spade," as he says, "black dirt was turned up, and at a short distance below the surface coal was found equal," in the opinion of persons supposed to be experts, "to the best Lykens Valley coal." To work the vein, a tunnel 330 feet long was cut at considerable cost. The "coal" was sent to Prof. Frazer for analysis; it was pronounced to be black slate, with a small percentage of carbon, and that chiefly graphite. It is one of the principal objects of a geological survey to save people from making mistakes like this of the Franklin County farmer.

Production of Near-Sightedness in Schools.—The effects of school-life, in producing near-sightedness in the pupils, have for some time been made the subject of systematic study by Dr. C. R. Agnew, of New York. In a recent address before the Medico-Legal Society, he stated the results of an investigation made in various schools of Cincinnati, New York, and Brooklyn. The number of students examined was 1,479, of

whom 630 were in Cincinnati, 549 in New York, and 300 in Brooklyn. Of the 630 Cincinnati pupils, 209 were from the district-schools, and of these 83½ per cent. had natural, or *emmetropic* eyes, while 10 per cent. were near-sighted. In the intermediate schools, 210 scholars were examined, and of these 80 per cent. were natural, and 14 per cent. near-sighted. In the normal high-schools, the eyes of 210 students were examined, and of these 78 per cent. were emmetropic, and 16 per cent. near-sighted. All this goes to show that near-sightedness is a progressive disease in the schools. The results for the other two cities teach the same lesson.

The 549 students mentioned above as examined in New York belonged to the New York College. Here, in the introductory classes, 57½ per cent. were found emmetropic, and 29 per cent. near-sighted. In the freshman class 42½ per cent. had natural eyes, and 40 per cent. were near-sighted. In the sophomore class no very material difference from what was observed in the preceding classes; but in the junior class 37 per cent. had natural eyes, and 56 per cent. were near-sighted. In the senior class 50 per cent. had normal eyes, and 37 per cent. were near-sighted. The Brooklyn students examined belonged to the Polytechnic Institute of that city. Here, in the academic department, 56 per cent. were emmetropic, and 10 per cent. near-sighted. In the collegiate department (a higher grade), 53 per cent. were emmetropic, and 28½ per cent. were near-sighted.

Astronomical Observations on the Rocky Mountains.—It is stated by Prof. Henry Draper, in the February number of the *American Journal of Science*, that, during two years when he photographed the moon every moonlight night at Hastings-on-the-Hudson, there were only three occasions when the air was still enough to give good results. Out of 1,500 lunar negatives, only one or two were really fine pictures.

Last summer, during a trip to the Rocky Mountains, he took with him a small achromatic, hoping to find more steadiness of the atmosphere at great elevations, but was disappointed. At Salt Lake City, 4,650 feet above the sea, Capella twinkled as badly, both to the naked eye and in the telescope, as he ever saw it at the sea-level.

At Fort Steele, near 7,000 feet elevation, Antares twinkled very much; and at Camp Douglas, 5,250 feet above the sea, the twinkling of several stars examined was surprisingly great.

At one point, however, he found the atmosphere without undulations, and the stars shone through it with a steady light. The central disk of Arcturus, he says, was hard and sharply defined; Antares near setting hardly twinkled at all; the moon was perfectly steady.

This point of observation was not far from Fort Steele, in the main range of the Rocky Mountains, at an elevation of 8,900 feet above the sea. Distant objects seemed near in the transparent air. The sky was not black, as he expected, but of a light blue; the moon, however, was near its full.

Another trial was made at Trout Lake, nearly 10,000 feet above the sea-level, and the air was found to be unsteady but transparent. At this point, however, intense cold, fierce winds, and heavy snow-falls, occur, making the location of an observatory here undesirable.

Dr. Draper concludes that the atmosphere in these high regions, although more transparent, is quite as tremulous as at the ocean-level at New York.

Influence of Heat on Galvanic Conductivity.—Till very recently it was held to be a law of Nature that the galvanic conductivity of all metals and metalloids is diminished by rise of temperature. It has been shown, however, that selenium is an exception to this rule, its conductivity being increased by heating. And now a further exception must be made in the case of tellurium, a body closely allied to selenium. We have already (in vol. x., p. 115) given an account of Siemens's researches on the action of light on selenium; we now present a synopsis of the results obtained by Franz Exner in his experiments with tellurium. Three bars of tellurium were prepared. Bar 1 broke before its dimensions were determined; bar 2 was 54 millimetres in length and 2.6 millimetres diameter; bar 3 was 153 millimetres in length and 3.73 millimetres diameter. Bar 1 was heated to 200°

Cent., and then slowly cooled. The resistance increased up to 90°, and thenceforward gradually decreased. In cooling, resistance steadily increased from 200° down to the room-temperature. This increase was so great that at the end of the experiment the resistance was six times what it was at the beginning, temperatures being equal. The same bar having been again heated from 20° to 200° Cent., there was no turning-point, and the resistance decreased steadily to the end, and increased continuously throughout in the cooling; but at the end the resistance was less than at the beginning.

Bar 2 behaved essentially like bar 1; the turning-point, however, was much higher, viz., 140°. With bar 3 five series of experiments were made, and with quite similar results. With the first heating there was a turning-point, which did not appear with after-heatings. At the maximum temperature, the resistance was pretty constant, while the resistances at the beginning and end of the experiments were very irregular.

Destruction of Germs at Low Temperatures.—Prof. Tyndall, in a communication to the London Royal Society, shows how heat, when discontinuously applied, though the temperature be below the boiling-point of water, effectually sterilizes organic infusions. In all such infusions, he observes, there is a period of latency preceding their clouding with visible bacteria. During this period the germs are being prepared for their emergence into the complete organism. They reach the end of this period of preparation successively, the period of latency of any germ depending on its condition as regards dryness and induration. The author's mode of proceeding is this: Before the latent period of any of the germs has been completed—say a few hours after the preparation of the infusion—he subjects it for a brief interval to a temperature which may be under that of boiling water. Such softened and vivified germs as are on the point of passing into active life are thereby killed; others not yet softened remain intact. This process he repeats well within the interval necessary for the most advanced of those others to finish their period of latency. The number of undestroyed germs is further diminished by this second heating. After a number of repetitions, which varies with the character of the germs, the infusion, however obstinate, is completely sterilized. The periods of heating need not exceed a fraction of a minute in duration. Sum them up in the case of an infusion which they have perfectly sterilized: they amount altogether to, say, five minutes. Boil another sample of the same infusion continuously for fifteen or even sixty minutes, and yet it is not sterilized, although the temperature is higher and its time of application more than tenfold that which, discontinuously applied, infallibly produces barrenness.

Extinction of a Prehistoric Race.—The extinction of the partially civilized race who once dwelt in the Rocky Mountain region was probably the result of some great geological change. The country is naturally arid, but doubtless when this nearly-forgotten people dwelt here in the numerous cities whose ruins are still to be seen the conditions of life were more favorable. The annals of this interesting race have perished with them, and the history of their downfall is now matter for conjecture. Mr. F. S. Dellenbaugh, of the Buffalo Society of Natural Sciences, describes as follows the course of events which resulted in the extinction of the Shinumos: When the change occurred, "the inhabitants, not understanding the science of irrigation, beheld their crops slowly but surely failing every year. The inevitable result was famine. By this their hardy constitutions were weakened, and the way was prepared for some great epidemic that swept away thousands, and left them in a melancholy condition. Then the epidemic was, possibly, soon followed by the appearance of the Indian, so entirely different from the Shinumo. He was ferocious, treacherous, cunning. Lying, cheating, stealing, murdering, were his pastimes. Then, it is no wonder that the Shinumo, in his emaciated condition, was compelled to retreat before the impetuous attack of such a foe. He was no warrior—no hunter. He had depended almost entirely on his knowledge of agriculture for his peaceful existence. It was impossible

for him to act on the defensive, and at the same time successfully till the soil. The Indian was constantly on the alert to surprise him. He must fall back and yield more territory to the exacting intruder. Vanquished and discouraged, he fortified himself in places extremely difficult of access; built cliff-houses; lived in caves, and finally became extinct. The divisions on the south side of the Colorado fared somewhat better, for the stupendous chasms of the river form a barrier that can only be crossed with success at several widely-separated points. Consequently, when the Indian reached this obstacle, his easy progress southward was interrupted. The crossing-points, too, which of course were well known to the Shinumos, had been strongly fortified by their soldiery, and thus a double check was presented to the invasion. The people then enjoyed comparative peace, till, in the course of their nomadic wanderings, the Indians discovered that there was an end to the cañon barrier, and were once more able to cope with their antagonists under favorable auspices. The Shinumos were again slowly driven back, and at the dawn of our knowledge of the region we find surviving only a mere handful of their kindred, in the Pueblo tribes, who were still defending their fortress-homes, as they had been for centuries."

Recent Outbreak of a Sandwich Island Volcano.—The volcano of Mauna Loa, Hawaii, was lately active for a few days, commencing on the evening of February 14th. A correspondent of the *San Francisco Chronicle* states that the outbreak was extremely sudden and violent:

"The point of activity was the old crater on the top of the mountain. When the eruption commenced, the flames suddenly burst from the mountain and formed a magnificent column of fire to the height of 16,000 feet above the summit. From the deck of the steamer Kilauea, lying at anchor at Kawaihae, five distinct columns of fire could be seen belching forth from the mountain, apparently not from the great summit crater of Mokuaweoweo, but from a smaller crater situated some miles distant from it, called Pohakuhanalei. A few days after intelligence reached Honolulu that the fire had disappeared, to the great disappointment of thousands who were preparing to start for the scene. But soon after news came that the great pyrotechnic exhibition of Nature still continued, and that the animation of the spectacle was enhanced by frequent earthquake-shocks. It is the general opinion that the stream of lava is flowing rapidly down the mountain-side toward Kahuku, in Kau. When last seen it had progressed a number of miles from the place of its first outbreak. The illumination was so brilliant that all parts of the island were lighted up. On the 24th the steamer Kilauea arrived with a party of excursionists at Kealakeakua Bay, the place where Captain Cook met his death. There they found that a submarine volcano had broken out near the entrance to the harbor the preceding night. About a mile from shore jets of red, green, and yellow fire leaped from the waters, interspersed with columns of steam and spray that glowed with innumerable rainbows, the spectacle being one of the grandest sights conceivable. In this locality the water is boiling and whirling like an immense caldron. Thousands of fishes are seen floating on the surface, ready cooked for the repast of swarms of Kanakas engaged in gathering the dainty abundance in their canoes. Large quantities of lava are also thrown up and float for some time on the surface. The matter is either buoyed by the intensely boiling water, or sustained by gases that gradually ooze from its pores. The submarine eruption is apparently from a fissure in the bottom of the sea, about a mile in length. It reaches the shore, and is traced inland between two and three miles. The flames on the water were first noticed by the natives at three o'clock on the morning of the 24th, and created much consternation. The depth of the water here was formerly from thirty to sixty fathoms; but, if the eruption continues, very likely a reef will be formed, which would render this bay one of the finest harbors on the Pacific. As far as known, no damage has yet attended the eruption."

How Science is advanced in Norway.—A correspondent of the London *Times*, *à propos* of the recently-published "Life of Thomas Edward," records an instance of liberal encouragement extended to a Norwegian naturalist. "Some years ago," says this correspondent, "there lived on the wild northwest coast of Norway a clergyman, with his wife, a large family, and a small income. He possessed two great advantages over Edward—a good education, and larger opportunities for observation. He, too, had the seeing eye, without which all opportunities are useless, and shortly it was known that science was being enriched by the hard-worked parish priest. The action of the Storthing was prompt. Though the majority of that body are poor peasants, and hold the purse-strings with a firm grip, they have the virtue of being liberal when good cause can be shown for it. They created a professorship of zoölogy in the Christiania University, endowed it with a

salary equal to £1,000 in England, and appointed the clergyman to the professorship, but without requiring either residence or teaching. How the professor went on enriching science with his discoveries, how he trained up his sons to follow in his footsteps, two of whom are now professors in the Christiania University, all this is known to scientific men, nor will they require to be told that the name of the clergyman was Sars."

Sir Wyville Thomson on the Theory of Evolution.—Sir Wyville Thomson said, in a lecture to the natural-history class at Edinburgh University, that the great stumbling-block, from the natural-history side of the question, in the way of an acceptance of the evolution hypothesis, was that any such passage from one species to another is entirely outside our experience. The horse had evidently been the horse since the earliest hieroglyphs were engraved upon Assyrian monuments and tombs; and the same held for all living creatures. There was not a shadow of evidence of one species having passed into another during the period of human record or tradition. Nor is this all. We have, in the fossil remains contained in the rocks, a sculptured record of the inhabitants of this world, running back incalculably farther than the earliest chisel-mark inscribed by man—incalculably farther than man's existence on this planet; and although we find from the record that thousands of species have passed away, and thousands have appeared, in no single case have we yet found the series of transitional forms imperceptibly gliding into one another, and uniting two clearly distinct species by a continuous bridge, which could be cited as an undoubted instance of the origin of a species. Mr. Darwin's magnificent theory of "natural selection" and "survival of the fittest" has undoubtedly shaken the veil by pointing out a path by which such an end might be attained; but it has by no means raised it. Still, even if we never found out the precise mode in which one species gave rise to another, there could be no further hesitation in accepting generally an hypothesis of evolution, and in regarding our present living races as the ultimate twigs of a great genealogical tree whose gradually coalescing branches we could trace, if our information were complete, to the dawn of geological time.

The Resources and Industries of Sudan.—At a late meeting of the Egyptian Geographical Society a paper on the Sudan was read, based on information collected by the late Munzinger Pasha. It was stated that there are few mountain-chains in the Sudan, but that granite ridges divide the region into well-defined districts, usually named after the rivers which flow through them. The country is, as a rule, fertile. The water-courses are mere torrents, which in summer are almost dry. The centres of population are few, and all the large towns are on the banks of the two Niles. Gold and copper are found, but the wealth of the country depends on agriculture and cattle-breeding. The population numbers about 5,000,000, consisting of Arabs and negroes. Industry is very much developed, and only articles of luxury need be imported. Stuffs, sword-blades, and leather of a very superior quality, are manufactured. The exports are chiefly ivory, gums, skins, etc. The people are nearly all Mohammedans, but their religion is mixed with numerous heathenish superstitions.

Extermination of the Grasshoppers.—Prof. A. S. Packard, Jr., has written to the *Tribune* a communication in which he advocates the project of affording Government aid toward the extermination of the Rocky Mountain locust. Locust years, he observes, are years of unusual drought, and seasons of drought occur every seven or eight years. In such summers the locust breeds in untold millions, and, the supply of food being short, they fly off hundreds of miles. A swarm observed by Prof. Robinson near Boulder City, Colorado, traveled a distance of about 600 miles to Eastern Kansas and Missouri. When seen at Boulder the swarm was on its way from the north, and may have come from some part of Wyoming. The general direction of the winds in July and August, along the eastern slope of the Rocky Mountains and on the Plains, coincides with the course of these swarms. If we would intelligently study the causes of the excessive increase and migrations of the locust, we must examine the meteorological features of the Western country, as-

certain the periods of drought and of undue rainfall, the average direction of the wind for the different months, in order to learn how far they correspond with the phenomena of locust-life. That there are cycles of dry and hot seasons recurring at irregular intervals, while the general average may remain nearly the same, century after century, is supported, though it may be vaguely, by observed facts. The author thinks that the remedy for locust visitations can be discovered and applied by a coöperation between the Signal Service and skilled entomologists employed by the General Government and the States most directly concerned.

NOTES.

It is proposed to occasionally issue from the Massachusetts Institute of Technology a "Circular," containing notes and queries on physical and chemical apparatus, processes, etc. It will be printed by the papyrographic process, and will be sent free to chemists and physicists, on condition that they from time to time communicate to the editors descriptions of apparatus and processes which they may have found convenient, and which are not in general use in laboratories. Applications for the "Circular" must be addressed to Chas. H. Weng, at the Institute of Technology, Boston.

A committee of the New York Medico-Legal Society, appointed to investigate the subject of "School Hygiene," recommend that the minimum age of admission to the public schools be six years; that the maximum attendance at school, for children under eight years, be three hours; that the schools be under medical supervision; and that schoolhouses should be surrounded on all sides with adequate open space, to secure light, ventilation, and play-grounds.

Since 1821 twelve ships have been abandoned in the arctic regions by exploring expeditions. Of these, but a single one, the Resolute, sent out with others under Sir Edward Belcher, in 1852, has been recovered.

There were three hundred competitors for the Boylston prize of the Medical Faculty of Harvard University for the best essay on the question of "Rest for Women." Dr. Mary Putnam-Jacobi, of New York, was the successful competitor. Her essay is said to possess extraordinary merit, and is to be published.

The medium of light-vibrations in the Torricellian vacuum is, according to Julius R. Mayer, extremely rarefied air. Air adheres to the glass and the mercury, and, on production of the vacuum, expands, and fills the space with a medium which conducts light like the ether in cosmical space.

A bronze statue of Livingstone, the missionary and explorer of Central Africa, will be erected in Glasgow during the present year.

In San Pete County, Utah, the hills abutting on Huntington Creek contain several valuable veins of coal. Seven mines have already been opened by drifts run from the faces of the hills. The coal yields a very fair quality of coke. These coal-fields appear to be of very considerable extent.

A piece of coral five inches in height, six inches in diameter at the top, and two inches at the base, was taken off a submarine cable at Port Darwin, North Australia. As the cable had been laid only four years, the coral must have grown to its present height in that time.

Prof. Huxley, in a recent lecture at the Royal Institution, on "The History of Birds," said that, as they now exist, birds constitute a perfectly well-defined group, nobody mistaking the forms included therein. But, when we turn to the geological record, the case is different. Fossil forms are found that present definitions do not embrace, indicating a wider range of structure, and the existence of types intermediate between birds and reptiles.

According to the *Gardener's Monthly*, the *Eucalyptus globulus* can hardly thrive in any of our States on the Atlantic seaboard, with the possible exception of Florida; there it is barely possible that a few Australian trees may live.

A correspondent of the *Lancet* writes that, when traveling in the upper Sikkim Himalaya, at elevations above 12,000 feet, he took whiskey in small quantities, to counteract the effects of strong exertion in a cold, rare atmosphere. The consequence was the reverse of what was expected, being drowsiness and lassitude, lasting an hour or more. Cold tea, on the contrary, was found to produce a feeling of exhilaration and capacity for renewed efforts.

In Calcutta the general death-rate of infants under one year among all classes of the population—Hindoo, Mohammedan, mixed race, and non-Asiatic—reaches the annual average of 480 per 1,000, the rate ranging from 184 among the non-Asiatics to 598 among the Mohammedans. Of every thousand Hindoo children born in 1875

there died 596 within the year, and of the Mohammedans no less than 735. Thus, a native child born in Calcutta has a chance of life considerably less than that of a person attacked by cholera.

DR. A. MCL. HAMILTON recommends the use of nitro-glycerine as a medicinal agent in epilepsy. One-tenth of a drop on the tongue at once produces cerebral hyperæmia. The face is flushed, the eyes become bright, and the temporal vessels throb, and there are marked sensations of fullness. Diluted in alcohol in the proportion of 1 to 100, nitro-glycerine can be kept safely.

SOME years ago a large tract of peat-bog was drained at Grangemouth, Scotland, the loose mud and moss being carried down the drains to the estuary. The consequence was, that the oyster-beds in the estuary were covered over with mud, and the bivalves entirely destroyed. "Nothing," writes Frank Buckland, "is so fatal to oysters as a mud-storm, except it be a sand-storm. The mud and sand accumulate in the oyster's delicate breathing-organs and suffocate it."

THE telephone appears to be well adapted for transmitting signals in mines; indeed, according to the *Mining Review*, telephones are already employed with great advantage in many of the deep workings of this country.

FROM soundings made by the U. S. sloop Gettysburg, the Challenger, and the German frigate Gazelle, a writer in *Nature* infers the probable existence of a submarine ridge or plateau connecting the island of Madeira with the coast of Portugal, and the possible subaërial connection, in prehistoric times, of that island with the southwestern extremity of Europe. A similar plateau connects the Canary Islands with the African Continent.

THE electric light has been under trial in English lighthouses nearly eighteen years. It was first tried at the South Foreland Lighthouse in 1858. An electric revolving light has been exhibited at the Souter Point Lighthouse, on the coast of Durham, for the last five years. The flash of this light has an intensity of about 392,000 candles. With the improved electric machines of Gramme or Siemens this enormous intensity of light could probably be increased five or six times.

SIDERAPHITHITE is the name of a new iron-alloy, composed of 65 parts iron, 23 nickel, 4 tungsten, 5 aluminum, and 5 copper. It is said to resist sulphureted hydrogen, is not attacked by vegetable acids, and only slightly by mineral acids. It is really more useful than standard silver, while it can be produced at a cost not exceeding that of german-silver. For alloys that have to be silver-plated to prevent oxidation, this material is a perfectly successful substitute.

THE two islands of New Britain and New Ireland, lying east of New Guinea, have been visited by a Wesleyan missionary, Rev. George Brown, who has explored 150 miles of the coast of the former, and 100 miles of the latter. Mr. Brown also crossed the latter island and made large natural-history collections. No white man had ever been seen inland before, but no opposition was offered to the explorers. Abundant evidences of cannibalism were found, but the natives live chiefly on bananas, cocoanuts, and pork, and have large plantations.

INTELLIGENCE has been received of the death of two eminent German travelers in Africa: Dr. Edward Mohr, author of "The Victoria Falls of the Zambesi," and the Baron Dr. Hermann von Barth-Harmanting. The latter died by his own hand at São Paolo de Loanda, while suffering from an attack of fever, in the thirty-first year of his age; the former died at Malange, in the same Portuguese colony of Angola. Barth was, at the time of his death, engaged in making a botanical and geological survey of the Portuguese African possessions, under government auspices; Mohr had but recently returned to Africa, sent out by the German African Society to explore the country west of the great lakes.

PROFS. C. V. RILEY, Cyrus Thomas, and A. S. Packard, have been appointed United States Entomological Commissioners, with headquarters at Washington. It is understood that the main object of this commission is to thoroughly investigate the haunts and habits of the Rocky Mountain locust, and to devise means of exterminating that plague, or limiting its ravages. Prof. Riley will occupy himself especially with the whole country east of the mountains and south of latitude 48°, together with the west half of Iowa and the whole of the British possessions. Minnesota, Nebraska, Southern Dakota, and Eastern Wyoming, have been assigned to Prof. Thomas; and Montana, Idaho, Western Wyoming, and the Pacific slope, to Prof. Packard.

A REMARKABLE appearance on the planet Saturn was observed by Prof. Hall, of the Naval Observatory, Washington, on December 7th. A bright spot suddenly appeared near the equator of the planet, spreading gradually till it resembled a band extending over 90°. The phenomenon continued to be visible for a month, but then the approach of the planet to the sun made further accurate observation impossible.

ALFRED RUSSEL WALLACE.